AGRICULTURAL ENGINEERING

Published monthly by the American Society of Agricultural Engineers

Publication Office, Bridgman, Michigan. Editorial and Advertising Departments at the Headquarters of the Society, Saint Joseph, Michigan

Subscription price to non-members of the Society, $3.00 a year, 30 cents a copy; to members of the Society, $2.00 a year, 20 cents a copy. Postage to countries to which second-class rates are not applicable, $1.00 additional. Entered as second-class matter, October 8, 1925, at the post office at Bridgman, Michigan, under the Act of August 24, 1912. Additional entry at St. Joseph, Michigan. Acceptance for mailing at the special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized August 11, 1921. The title AGRICULTURAL ENGINEERING is registered in the U. S. Patent Office.

O. B. ZIMMERMAN, President — RAYMOND OLNEY, Secretary-Treasurer

Vol. 8 — JULY, 1927 — No. 7

CONTENTS

BASIC PRINCIPLES INVOLVED IN THE DESIGN OF THE SMALL FEED GRINDER 167
By W. C. Krueger

RAMMED EARTH FOR FARM BUILDINGS 172
By Karl J. Ellington

ADOBE STRUCTURES FOR EARTHQUAKE REGIONS 173
By J. D. Long

ROTARY TILLER COMBINED WITH TRACTOR DRIVEWHEEL 175
By E. G. McKibben

RESEARCH ON WOOD PRESERVATIVES 176
By H. T. Barr

THE EFFECT OF GROWTH UPON THE CAPACITY OF DRAINAGE DITCHES 177
By C. E. Ramser

OBSERVATIONS ON ELECTRIC BROODING 181
By J. E. Dougherty

FACTORS INFLUENCING SOIL MOISTURE REGULATION 183
By R. W. Trullinger

RESEARCH IN AGRICULTURAL ENGINEERING 187
—Kinematics and Dynamics of the Wheel-Type Farm Tractor
By E. G. McKibben

GRAPHIC ANALYSIS AS APPLIED TO THE STUDY OF THE WHEEL-TYPE TRACTOR .. 190
By J. N. LeConte

AGRICULTURAL ENGINEERING DIGEST 192

EDITORIALS 194
—Agricultural Production Costs
—Going Ahead
—Are We Ready?

A.S.A.E. AND RELATED ACTIVITIES 195

Bearing Experience

—that is older than the modern power farming machine industry

EVEN in the days when the gasoline tractor and modern power farming machinery industry was in its infancy, Hyatt was a leading manufacturer of anti-friction bearings.

The first tractor and power machinery bearing problems were naturally referred to Hyatt, and Hyatt was able to offer mature counsel and practical assistance which contributed largely to the subsequent rapid development of this equipment.

Since that time Hyatt and the power farming machine industry have been closely allied. By research and experimentation, by utilizing its vast resources in an unrelenting quest for better metals and better methods, Hyatt has rendered an indispensable service.

Thirty-six years of knowing how, is the enviable record behind Hyatt today. Manufacturers are thus assured of bearings that will faithfully uphold the reputation of their products.

HYATT ROLLER BEARING COMPANY
Newark Chicago Detroit Pittsburgh Oakland

HYATT
ROLLER BEARINGS
PRODUCT OF GENERAL MOTORS

AGRICULTURAL ENGINEERING

The Journal of Engineering as Applied to Agriculture

Vol. 8 JULY, 1927 No. 7

Basic Principles Involved in the Design of the Small Feed Grinder*

By W. C. Krueger[1]

THE problem of feed reduction has always been of vital interest to Wisconsin farmers. From the time of the first horsepower burr mills to the largest present day attrition mills the progress in mill development has been towards faster, cheaper and more economical grinding. Custom mills operated by water power or steam supplanted the use of the individual horse-operated mills. The development of the gas engine, however, resulted in a revival of the individual farm mill, improved and reduced in cost by this time. Fast upon the heels of this development in farm power use came the application of electricity to power uses. Extension of this service by high-tension distribution lines made cheap power available in many a village and country town. Custom grinding again saw a revival. The direct-connected attrition mill produced feed superior in quality to that made by the farm mills; it ground a load of feed while the farmer marketed, and ground it fairly cheap. But the farmer often went to town only to have feed ground; the trip took a half day at least, and the services of one man and a team. The farm work waited.

Rural electrification brought with it power at the turn of a switch. A renewed interest in farm feed grinding was early manifested by progressive farmers. They wanted to operate their mills with electric motors, sparing themselves the frequent and time-wasting trips to the custom mill or the uncertainties of gas-engine operation in cold weather, etc. They asked for information regarding speeds, also methods of speed reduction to accommodate the comparatively slow-turning burr mill when operated by a motor; they wanted to know which mills were most economical—which mills to buy.

Isolated installations of electrically operated mills had already indicated that a material cash saving could be made by home grinding as compared to taking the grain to town, exclusive of the cost of hauling. The increased use of electricity was beneficial to the farmer in building up his load to the point of reduced rates and beneficial to the utility in supplying increased revenue.

To supply the farmer and the utilities with information on feed grinding by electric motors and be in a position to advise, the Wisconsin Committee on the Relation of Electricity to Agriculture undertook the study of farm feed mills.

The first series of comparative tests were run in 1924-25. Some twenty mills were obtained and studied. Of these, nine produced results justifying further study. Extensive tests resulted in the choice of three mills for placement on the test farms. In general, the tests showed that a more satisfactory product was obtained from the rigid burr type of mill than from the floating burr type mill. Very small burrs did poorer work, especially on oats, due to the narrower grinding surface. Radially cut and crow-foot burrs both produced good results. No definite recommendation could be made on the mills because of the wide discrepancy in results and the difficulty in controlling all the factors during the tests. The following table is presented as a record of the most representative tests made on the selected group of nine mills:

Results obtained from three installations on the Ripon experimental electric line show wide variations in operating efficiency under varied farm conditions. On a basis of 4½ tons grinding per month, the power consumption was 14, 18 and 70 kw-hr.

Feed Grinding Test Results with Oats

Name of mill	R.p.m.	Mechanical Analysis On No. 10	On No. 20	Through No. 20	Lbs. per hp.-hr.
Baker	850	11.5	33.0	55.5	117.2
J. B., Jr. No. 1	4500	9.1	49.9	41.0	142.0*
Kelley-Duplex	1310	16.5	35.5	48.0	74.0
Letz	600	16.5	31.5	52.0	63.5
New Holland	1010	20.0	33.0	47.0	86.7
Rowell	820	12.0	34.5	53.5	50.8
Sandwich	557	18.0	23.0	59.0	36.8
Stover	400	15.5	32.0	52.5	38.1
Williams	3300	1.0	50.0	49.0	53.0

*5/16 in. screen

The highest labor efficiency in farm feed mill use is obtained when the grain is supplied to and removed from the mill without personal attention. The highest economy in electric power use is obtained by using a small motor for long periods of time rather than a large motor for a short time. Farm experience showed that the hammer mill was better adapted to these conditions than the burr mill, because (1) it is not dulled by running empty; (2) foreign material in the feed will not ordinarily injure it, (3) there is a greater range in fineness; (4) replacements are fewer, and (5) wear does not impair its efficiency.

The following data illustrates the necessity and economy of replacing burrs as soon as they become dulled:

1. A mill with badly worn burrs produced 100 lb. coarsely ground oats in 5.5 hrs, using 4.75 kw-hr.
2. The same mill with new burrs produced 100 lb. medium ground oats in 5.5 hrs., using 4.75 kw-hr.
3. Burrs cost from 60 to 80 cents per pair.

However, no mill was discovered that would meet all of the following requirements we considered essential on a farm feed mill:

1. Produce a satisfactory product
2. Require not to exceed 5 hp.
3. Not require an attendant
4. Be economical in operation
5. Be reasonable in first cost
6. Be durable and simple

It was to determine the basic operative factors and to aid in the development of a satisfactory feed mill that the second series of grinder investigations was begun. This series had two objectives, the first being the determination of factors influencing the performance of small feed grinders especially adapted to electric operation and, second, the promotion of the development of satisfactory mills, as such mills were not on the market so far as we were able to find out.

In view of the fact that the hammer mill offered the greatest promise, the work was practically confined to mills of this type. The investigations included the following studies:

1. Development of a satisfactory feeding method
2. The relation between speed, capacity and efficiency
3. The effect of shape, spacing, number and position of hammers on capacity, power and fineness
4. Factors determining fineness
5. The effect of the blower and its design and location on the capacity and power requirements of hammer mills.

*Paper presented at the 21st annual meeting of the American Society of Agricultural Engineers, at University Farm, St. Paul, Minn., June, 1927. Contributed by the Rural Electric Division.

[1]Project leader, Wisconsin Committee on the Relation of Electricity to Agriculture. Assoc. Mem. A.S.A.E.

Equipment for the Tests. (Fig. 7.) The power unit consisted of 5 hp. 1200 r.p.m. cradled dynamometer motor. The torque of the motor was recorded by a Gulley traction dynamometer in most tests and on a small platform scale in cases where the horsepower requirement was held constant.

The dynamometer torque arm reacted against a specially built hydrostatic unit having a one-square-inch piston, which actuated the recording mechanism. The Tabor indicator used in the standard Gulley machine is equipped with a one-fourth-square-inch cylinder. This was replaced with a one-half-square-inch cylinder, making the spring scale read direct. For example, a one-inch pencil movement would equal 20 lb. when using a 20-lb. spring. The dynamometer was driven at such speed as to give two inches of paper travel for each 1000 revolutions of the motor. Trials indicated that the integrator was quite accurate for the steady loads encountered in grinding. Use of the integrator in connection with a stop watch gave us horsepower and horsepower-hour data.

Mill and Feeding Arrangement. (Fig. 8) The mill was fastened to an adjustable test stand and belted to the motor. Uniform belt tension for all of the tests was assured by the use of a spring balance. A threshing machine auger conveyor which could be operated at eight different speeds provided eight definite and accurate rates of feeding. Practically all of the tests were run on oats, experience proving that oats is about the most difficult grain to reduce.

Procedure. The mill was operated under load long enough to insure uniform conditions before each test. Test runs usually were for one minute when the scales were used for measuring power, and for a period of one and two-thirds horsepower-minutes on the integrator when the recording dynamometer was used. The feed obtained during these periods was weighed and representative one quart samples taken for mechanical analysis.

Mechanical Analysis. (Fig. 5.) The samples of ground feed were analyzed by sifting them through the Tyler standard screen series, size numbers 8, 14, 28, 48, 100. This conforms very closely to the United States standard. A Ro-Tap shaker was used, a time clock limiting shaking periods to five minutes. Fineness was recorded as the accumulative percentages of feed retained on the several screens, beginning with the coarsest.

To facilitate comparisons, the results from each sample were expressed by the fineness modulus proposed by E. A. Abrams of the American Society for Testing Materials, which has been generally accepted by workers as standard for the expression of fineness grades of concrete aggregates. The modulus for any sample is the sum of the percentages of material coarser than each of the given sieves in the series.

Moisture was determined by the soil method: 50 grams of the sample and 150 cc. of oil boiled together for 20 minutes at 195 deg. C., and the moisture distilled from the grain condensed into a thistle tube and measured.

The variation in moisture was small—from 10.6 to 12.6. The majority of the material was 10.8.

Results. A comparative study of hammer mills has as its prerequisite an understanding of the characteristics and variables of hammer-mill operation. An I. B. Rowell No. 1 mill was obtained from the manufacturer for this study.

Given a certain mill and a uniform grain, the variables in mill operation are reduced to (1) speed, (2) rate of grinding (3) fineness, and (4) horsepower requirement. Of these four, horsepower is a derivative of the other three and cannot be regarded as primary.

To determine the values of these variables the following series of tests were run:

Series I—Speed—effect on
1. Rate of grinding
2. Fineness

Series II—Rate of grinding—effect on
1. Power
2. Fineness

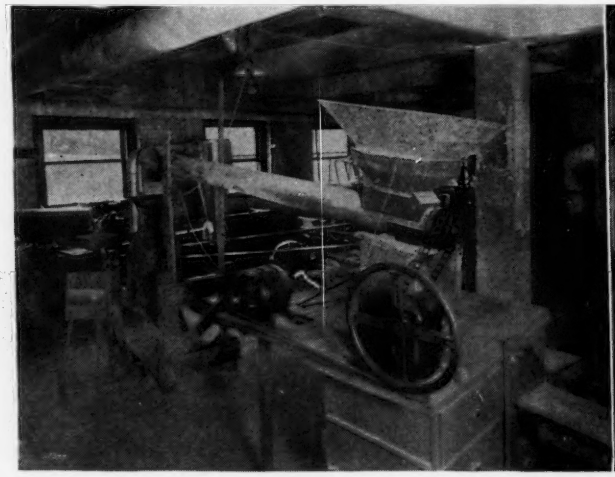
Series III—Fineness of grinding—effect on
1. Power
2. Rate of grinding

The Effect of Speed on Fineness and Capacity. (Fig. 1.) Series I consisted of seven runs, representing seven speeds ranging from 1320 to 3510 r.p.m. The power was held constant at 3 h.p. The test was repeated for all three screens, 3/16, 4/16 and 5/16 in.

Results, as shown in Fig. 1, indicate that the capacity increases as the speed decreases, though not in direct proportion, and that the product becomes coarser. The declination of the 3/16-inch screen curve indicates a lack of screening area for the amount of meal produced. It would seem that the graphs would approximate a straight line, if the screening area was adequate and all other factors remain relatively constant. Definite conclusions regarding the proper speed would require a large number of tests on screens of fine gradations; this we have not so far been able to do. However, the limited amount of data we have points to the theory that a larger screen at high speeds will produce the same product as smaller screens at slower speeds, and more efficiently. This is no doubt also affected by the effective area of the screen.

Rate of Feeding. (Fig. 2.) By holding the speed constant and regulating the feed, a study was made of the effect of the effect of the rate of feeding on fineness and power.

Horsepower is directly proportional to the rate of feeding, the power increase rate being practically the same for the 4/16 and 5/16-in. screens. The horsepower with the 3/16-inch screens increased more rapidly due to the limited screen area. Capacity beyond this point is maintained by the mushing action of the hammers forcing the feed through.



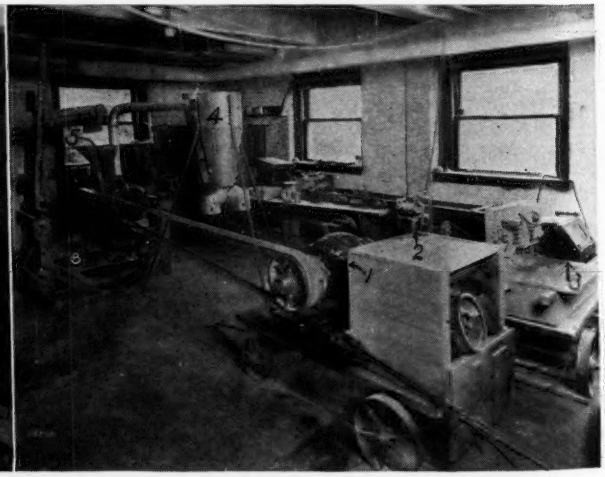


Fig. 7. (Left) Thresher cross conveyor, motor driven through worm gear reduction. Eight feeding rates by step pulley and sprocket changes. Note the manometer panel for air pressure readings. Fig. 8. (Right) Showing the arrangment of the test units; Motor (1), gear box (2), dynamometer (3), collector-bagger (4), and feed mill (5)

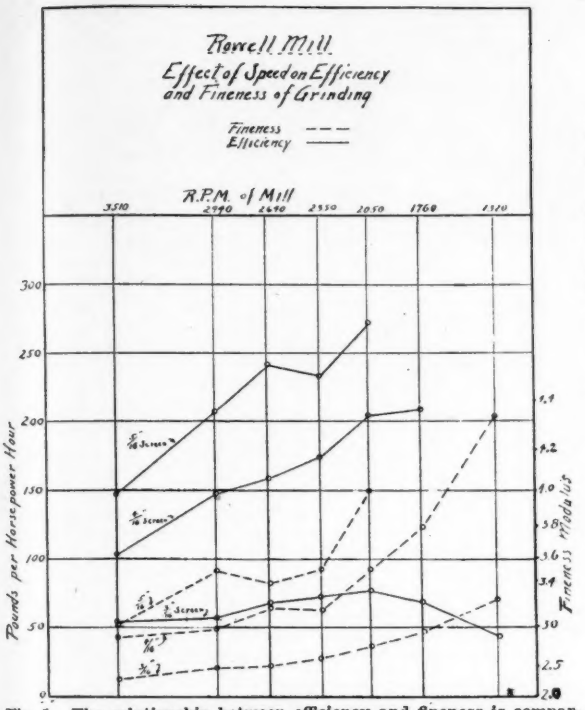


Fig. 1. The relationship between efficiency and fineness is comparatively constant for the entire speed range. Modulus graphed to represent actual increases in the size of feed particle, according to the curve of Fig. 5

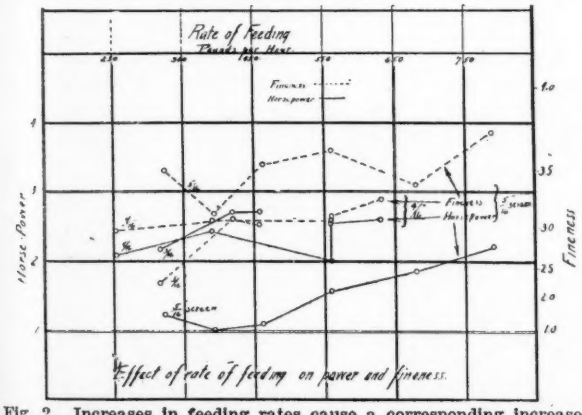


Fig. 2. Increases in feeding rates cause a corresponding increase in power consumption and coarseness of particle

The fineness varied in inverse proportion to the rate of feeding and was reflected in every horsepower change, indicating that for each set of conditions there is a critical point in the quantity fed a hammer mill at which the mill is most efficient and at which a heavier or lighter feed results in either a coarser product or fewer pounds per horsepower-hour, or both.

Feed reduction seems to be affected by the action of the hammers plowing through the layer of material on the screen. The thickness of this layer constitutes the critical factor in the rate of feeding.

Fineness as Affecting Mill Capacity. Increasing the rate of feeding for each screen to the point of overloading and recording the capacity at this setting, gave the screen rating.

The 3/16-in. screen gave 464 lb. per hr., the 4/16-in. 72 per cent more than that and the 5/16-in. 112 per cent increase. The 3/16-in. screen required 3.74 hp., the 4/16-in. 7½ per cent less, and 5/16-in. 11.3 per cent less.

The fineness for the 3/16-in. screen was 2.91, for the 4/16-in. 3.139, and for the 5/16-in. 3.418. These tests were run at 2640 r.p.m. Other speeds would change the value of the

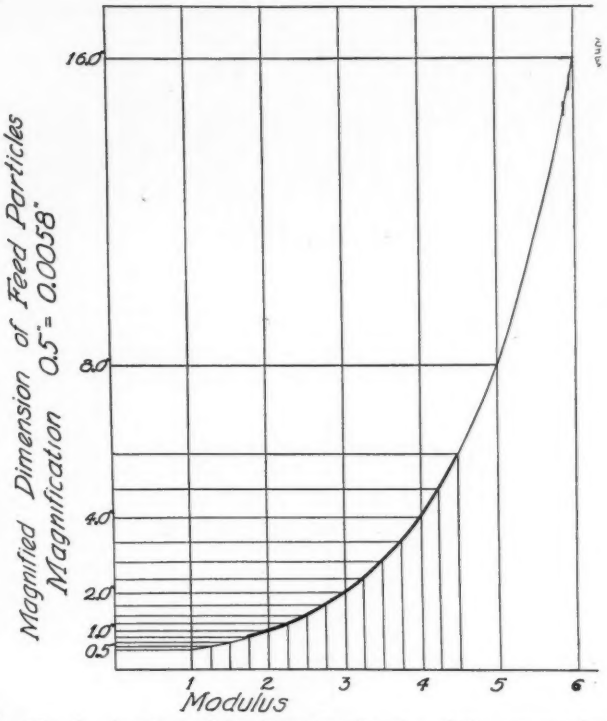


Fig. 5. As the modulus increases, the size of the average feed particle representative of that sample increases, following the geometric ratio $T_n = AR^n - 1$. Use of this chart permits graphic representation of actual finenesses for comparison

results, but not materially affect the relationship between screens.

Summary of Factors Influencing Fineness. There are probably but three basic principles of reduction involved in a hammer mill: (1) Explosion due to impact; (2) cutting by edges of hammers, and (3) attrition or rubbing action.

Velocity of Hammers. At high speeds the feed is carried around almost parallel to the screen surface, making the openings only partially effective. The result is the same as though a smaller size screen was used at slower speeds, for at slower speeds the grain impinges against the screen at a greater angle and more and coarser feed passes through.

The use of thinner screen stock gives better results. Woven screens have an advantage over punched screens, in that they have a larger effective screening area and also because it appears that the roughness holds the feed better.

Initial Hammer Impact. The general idea that the initial impact of the hammers against the feed does the grinding was not substantiated by our tests. Removing the screen produced a hulled and cracked grain product, varying with the speed, but never satisfactory. We believe that an area of high pressure pads the hammer faces, particularly in the broader hammers, preventing a sharp impact. As evidence of this, when lint covered the individual hammer faces the performance approximated that of the standard set-up.

Rate of Feeding. For any particular speed the rate at which the feed may be introduced into the mill is determined by the total area of the screen perforations and by the total number of perforations.

Screening Area. Screen area limits the passage of ground product, holding it in the mill longer than essential for certain reduction, resulting in a finer product.

Fan. The use of a fan seems to result in a coarser feed and an increased capacity. In quite a few tests no difference in rate or fineness was noticeable.

The Rotor. Factors involved in rotor construction are:

1. Number, shape and size of hammers per row
2. The spacing of hammers with regard to other rows, as staggering
3. The number of rows of hammers
4. Swing and rigid hammer

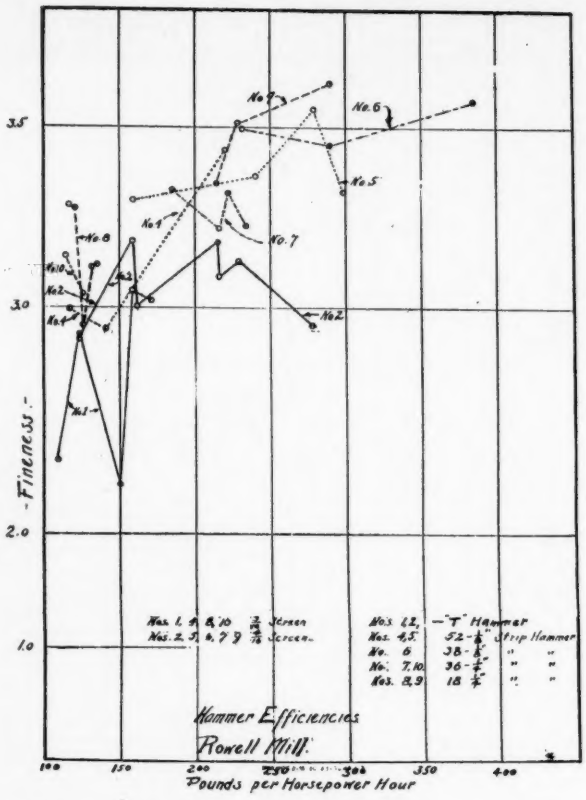


Fig. 3. Graphing fineness against efficiency affords a means for comparing different mills, or the effect of changes in one mill. The T hammer is the most efficient, as shown by curves 1 and 2

The mill came equipped with four rows of three T-shaped hammers. Sets of flat strip hammers, 2/16, 3/16 and 4/16 in. in width, were also supplied. Alternate short and long T-hammers gave poor results; also two rows of T-hammers gave poorer results than four rows. In all other tests four rows were used, in the following combinations: 18 hammers of ¼-in. stock; 32 of 1/16-in., 48 of 3/16-in., 38 of ⅛-in., 52 of ⅛-in.

1. The results (Fig. 3.) indicate that the more nearly solid the cross line of the hammer rows is, the better the results obtained, with the T-hammers presenting an almost solid cross line giving the best results. This apparently applies only to mills of the Rowell type. The Prater mill, which is of radically different type, successfully uses a different hammer arrangement.

2. Results we have been able to obtain show no advantage in staggering hammers.

3. On the Rowell mill four rows of T-shaped hammers gave better results than two rows; also on the Prater mill three rows gave better results than two rows. This might indicate the desirability of still a greater number of rows of hammers, assuming other adjustments to be approximately the same.

This would seem to be further proved by experience which shows quite conclusively that all of the grinding is done by the extreme tips of the hammers plowing through a fluffy whirling layer of material between the periphery of the hammers and the housing.

All the experiments tend to indicate that with the cereals the attrition or rubbing action is by far the most important, and that the explosion, due to initial impact, is negligible. With corn and other heavy and brittle material impact is probably of greater importance.

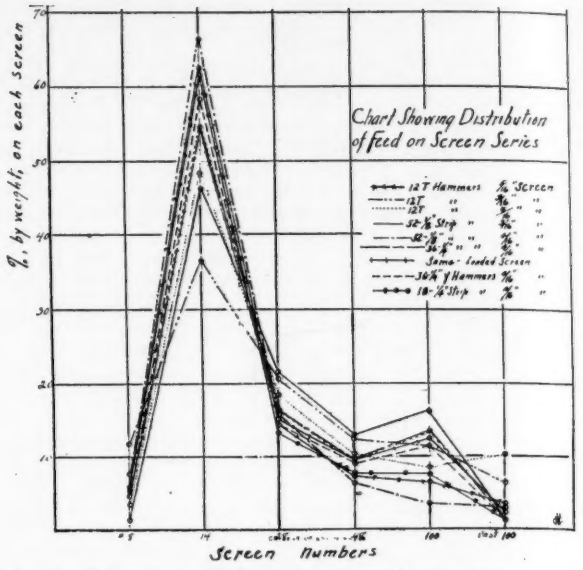


Fig. 4. The screen separations from hammer mills follow a characteristic form. Note the effect on feed distribution of various hammer types and sizes

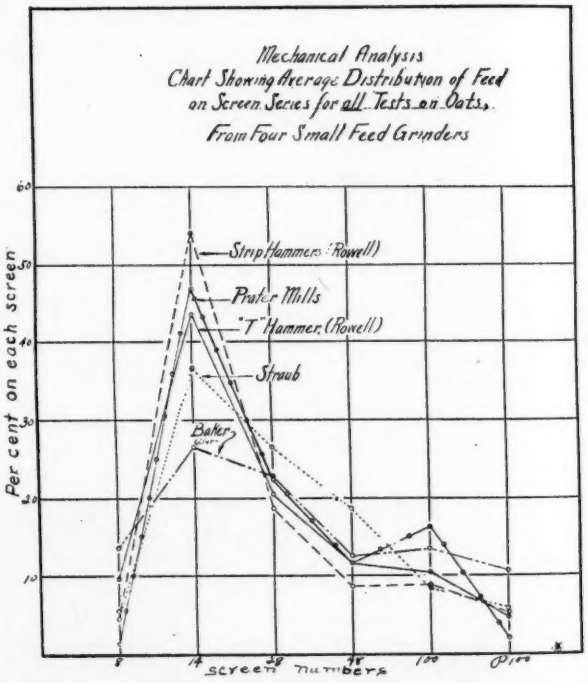

Mechanical Analysis
Chart Showing Average Distribution of Feed on Screen Series for all Tests on Oats, From Four Small Feed Grinders
Strip Hammers (Rowell)
Prater Mills
"T" Hammer (Rowell)
Straub
Baker
Per cent on each screen
Screen Numbers

Fig. 6. Each type of mill and hammer produces a meal individual in its characteristics, as shown by the screen separations

4. The choice between swing or rigid hammers can apparently be made without regard to grinding effect, being merely an opinion of the safety afforded by the nonrigid set-up or the facility for making replacements.

Position of Intake. In view of the fact that the initial impact seems to be of minor importance in reduction, the position of intake can be determined solely by convenience of design and by the suction-fan action produced by the rotor. Examples of this are the suction intake near the shaft on the Straub and the injector type intake on the Rowell. The Prater has an intake near the shaft, but the rotor produces no suction.

Development of Satisfactory Feeding and Feed Removal Apparatus. The biggest labor economy in the use of mills is obtained when grain is supplied the mill and the ground feed removed without the necessity of an attendant.

Therefore, a simple, positive, uniform and nonclogging feeding mechanism must be provided, and of such design that an ample storage hopper can be used. It should permit of definite adjustments in feeding rate, so particular settings can be duplicated.

The present design of small hammer mills will not accommodate the automatic feeding of ear corn, which is desirable in some sections. This obstacle to this use of the mill can be overcome by the addition of a cob crusher.

Removal of Ground Feed From the Mill. In many cases it is impractical to mount the mill over ground feed bins; therefore, means for removing and elevating the feed from the mill seems essential to best practice.

A fan appears to be the simplest and cheapest solution of the problem. It requires a small amount of additional power—less than 1/3 hp. for either the Prater or Rowell mills to move the feed 20 and 40 feet for the usual feed capacity; it places the feed anywhere a pipe can reach, and distances of 20 and 50 feet are spanned as readily as 6 and 12.

Summary of Tests. The prime motive for the work which we have done has been the promotion and development of grinding equipment that meets the six requirements which we considered essential for small electrically operated farm mills.

As stated previously, the hammer type mills have met these requirements to a fuller extent than have the burr type of mills. The burr mill used for comparative tests was selected on the basis of previous studies as one of the best in its class in approximating these requirements. Two of the hammer mills worked with have now met every requirement. (Figs. 9 and 10.) They produce a satisfactory product, draw less than 5 hp., are durable and simple, economical in operation, equipped with blowers and improved feeders and reasonable in first cost.

While we have not run tests on larger mills, either hammer or burr, the information we have been able to obtain on such mills indicates that these small mills will at least approximate, if not exceed, the efficiency of the larger mills.

OFFICIAL REPORT OF WISCONSIN FEED GRINDER TESTS
January 1 to June 1, 1927

Specifications

Name of mill	Type	Size	Bearings	Automatic Feed	Fan elevator
Baker "Monitor"	Burr	6 in.	Babbitt	Yes	No
Prater	Hammer	No. 2, 3, 5	Babbitt	Yes	Optional
Rowell	Hammer	No. 1	Ball	Yes	Optional
Straub	Hammer		Ball	No	No

Size—inches	Speed—r.p.m.	Screen—inch	Lb./hr.	Hp.	Lb./hp-hr.	Modulus
		Baker Mill				
6	780	Fine burrs	152.0	2.41	63.0	2.350
6	780	Fine burrs	161.5	2.17	72.0	2.489
6	780	Coarse burrs	232.0	1.56	148.5	2.692
6	780	Coarse burrs	249.0	1.62	153.0	2.812
6	780	Fine burrs	193.5	2.32	83.3	2.833
6	780	Coarse burrs	183.5	1.15	159.5	2.859
6	780	Fine burrs	187.0	0.99	189.0	3.212
		Prater Mill				
2	2050	1/16	116.0	2.50	46.5	2.620
2	2055	1/16	100.5	2.00	50.3	2.720
2	2055	1/16	52.5	1.00	52.5	2.752
2	2680	5/64	218.0	2.00	109.0	2.993
2	2050	1/8	135.0	1.00	135.0	3.365
2	2050	1/8	253.0	2.00	126.5	3.419
3	2050	1/16	116.0	2.00	58.0	2.580
3	2020	1/8	360.0	3.00	120.0	3.152
5	2030	1/16	510.0	5.00	102.0	2.971
5	2030	1/8	872.0	5.00	174.8	3.408
		Prater Mill (Shelled Corn)				
2	2050	1/8	1155.0	2.0	577.5	3.144
3	2020	3/16	1960.0	3.0	652.0	3.912
2	2050	1/4	2115.0	2.0	1057.0	4.014
5	2020	1/4	4837.0	5.0	967.4	4.095
		Prater Mill (Ear Corn)				
3	2020	3/16	790.0	3.0	263.3	3.591
5	2020	3/16	1356.0	5.0	271.2	3.705
2	2050	1/4	865.0	2.0	432.5	4.092
5	2020	1/4	1720.0	5.0	344.0	4.110
		Rowell Mill				
1	3510	3/16	159.6	3.00	53.2	2.308
1	3770	3/16	746.0	5.71	130.5	2.782
1	3950	4/16	631.0	4.12	153.0	2.951
1	3950	3/16	876.0	5.26	166.5	3.096
1	2640	4/16	568.0	2.63	216.0	3.097
1	2640	4/16	792.4	3.46	229.6	3.139
1	3945	4/16	890.0	4.45	200.0	3.204
1	2640	4/16	518.0	1.78	290.0	3.439
1	2640	5/16	566.0	1.58	358.0	3.631
		Straub Mill				
"Quaker	1955	5/64	115.3	5.95	19.3	2.309
City"	3100	1/8	276.0	5.32	51.8	2.629
hammer	3100	1/4	366.0	3.05	120.0	3.325
mill	3100	1/4	538.0	3.26	165.0	3.390

NOTE: All the above tests were conducted on mills without fans. The use of the fan would increase the total power required by ¼ to 1 hp., depending on the amount of material moved and the distance to which it must be blown.

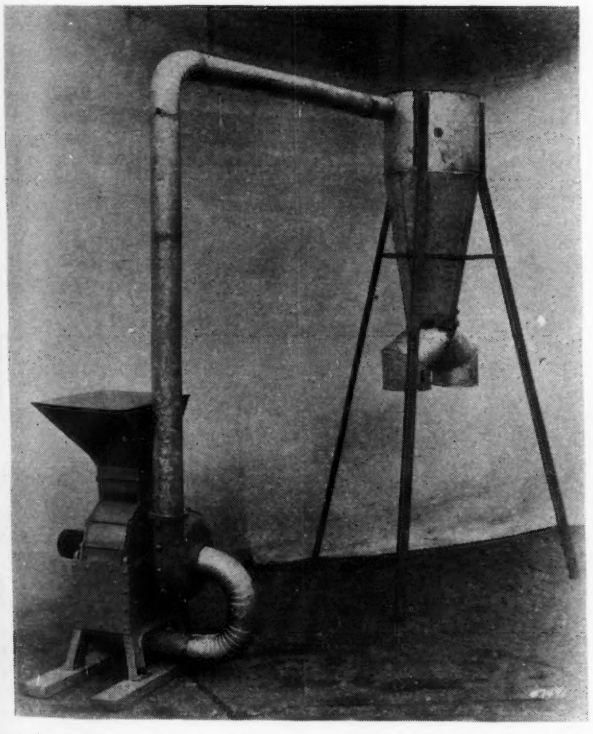


Fig. 9. The Rowell No. 1 hammer mill equipped with blower fan and collector-bagger

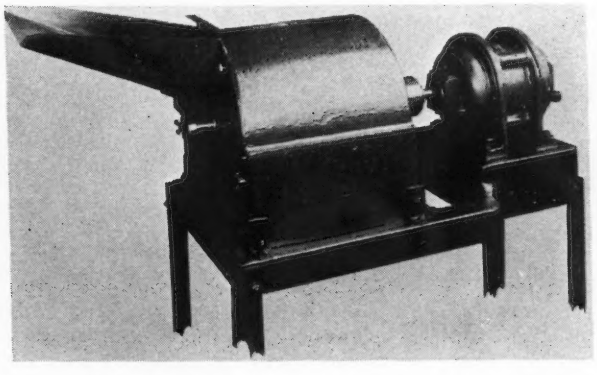


Fig. 10. The Prater No. 2 hammer mill direct connected to an electric motor

Rammed Earth For Farm Buildings

By Karl J. Ellington

IF THE method of constructing buildings of compressed or rammed earth (pise de terre) were utilized wherever economical to do so, it would mean a national saving amounting to many millions every year. And the greater part of this saving would be for the American farmer, since on the farm we have the ideal conditions for getting at the minimum cost when using this material. The farmer's own soil often is just the right kind, waiting right at the building site or close by.

To make this building method known to all farmers is a task of importance, just as important as anything about crops and machinery, whereby farming conditions can be bettered. And it must not be surmised that lower cost in building is the only merit pise is offering. If built right, a rammed earth building is nearly indestructible. There can be less insurance costs both for the building itself and for what is in it. It is cool in summer and warm in winter. A well-built pise house is too much for a tornado and can even outride an earthquake better than any of the houses we now have on the farms.

But to make the rammed earth method a matter of common knowledge among the farmers will require educational effort. I am sure that the best and quickest way to reach that aim is for the agricultural engineers to take the matter up in earnest and first satisfy themselves that pise construction has all the merits claimed for it—and then go ahead with the demonstration work that may be needed to get the thing going.

There are two good reasons why the agricultural engineers should do this work. The first is that they carry the authority necessary to break down the prejudice and disbelief that stand in the way. The second reason is that they can be relied upon to build right and show up the real merits of pise—and perchance make improvements yet possible in regard to time-saving and sundry constructional details.

From fifteen years given exclusively to pise building and to propaganda for the method, I have gained some experience also in regard to the importance of having the first samples of pise building carried out the right way so as to do justice to the method and not a harm to its good name and an injury to the many expectant farmers around who would need to use it. I have seen many self-builders do first-class work, but I have also seen some of them getting miserable results, in most cases from insufficient information on the subject before building. Again I have observed that contractors or persons building for profit may not always be the most suitable parties to pave the way for pise in new territory.

There being as yet not much literature or detailed information available on the subject of pise and pise building some agricultural engineers may feel somewhat uncertain as to how it will act on certain points, such as thermal conductivity, insulating properties, need of reinforcements, and so forth. But there is nothing in pise that stands in the way of using it in building the most up-to-date dwelling house as well as any and all outbuildings needed on the farm.

Because there are a variety of kinds of soil and mixtures of soils suitable for pise building, it is rather difficult to give specific data as to thermal conductivity. But any of these earths rammed have a greater safety margin than any other material, in placing smoke channels and ducts for hot and cold air. Such channels and ducts may be constructed as the work on the wall progresses. Similar provisions can be made for pipes and electrical wiring, if these details are on the blue prints, but grooves for wiring may also be cut afterwards with a tool made for that purpose.

In regard to reinforcement it is not necessary to have much of it. I have found that barbed wire comes in very handy, also pieces of discarded wire rope, old chains and links and similar junk. If wooden strips or lath are used they should be thin and have rough surfaces, and they must not be dry when placed in the form, but should be thoroughly damp or they will absorb dampness from the pise, swell, and crack the wall.

It should be kept in mind also that there is some contraction going on in a newly rammed section of wall and that it therefore is better with short pieces of reinforcement, interlapping them, than with longer pieces. The amount of contraction will vary not only according to how much clay, sand, pebbles, etc., there are in the mass, but also according to different degrees of moisture present when ramming. In most cases a little reinforcement in corners and over doors and windows is sufficient.

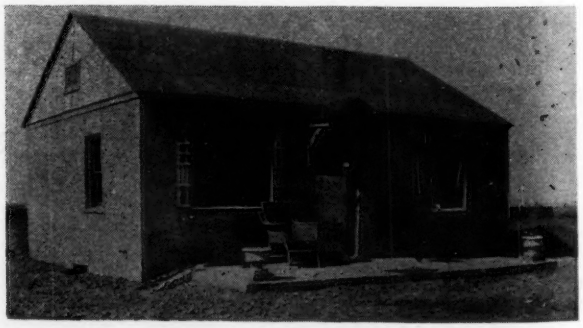
Pise walls should not be less than 12 inches thick anyway—and preferably 16 or 18 inches. Thin walls may get out of plumb when drying, especially if not shaded so that inside and outside will dry out at the same rate. But if the wall is built with pise blocks, well dried beforehand, there will be very little shrinkage to reckon with.

Then there is the question of ramming by machinery. In my book, "Modern Pise-Building," I have pointed out that where two or more persons are ramming in the same form they should avoid "keeping time" or ramming in unison. From this some of my correspondents seem to have drawn the conclusion that perhaps ramming by machinery would be detrimental to the wall. But a mechanical ramming contrivance need not and should not be so constructed that any two or more tampers strike simultaneously. Nor should a tamper be too heavy or otherwise produce blows exceeding a certain limit. The idea is that too heavy or too forceful strokes may make the stricken spot sag down enough to make small cracks to the right or to the left, and such a little crack may take the notion to serve as a starter for a real and visible crack as the wall dries.

Although a pise wall, if carefully rammed, will have a smooth and hard surface, making it remarkably weather resistant, it is nevertheless desirable to apply some protective coating and let time and weather wear on this instead of on the wall itself. But whatever coating is to be used, it should not be applied until it is sure that the last remnants of moisture in the newly built pise wall have wandered out even from the center part of the wall. It is well to let two or three months elapse before applying the coating, or postpone it until the year after building.

There are many different liquid mixtures that can be used. In my book on pise building are several different recipes for such coatings. They cannot all be repeated here. Mixtures such as a solution of silicate of soda, a lime wash made with boiling water, hot coal tar, or a solution of bitumen, resin or paraffin in light oils give good results. A coating that will wear very well is hot tar with sand thrown on while the tar is soft. After drying this can be whitewashed, or first coated with dilute cement mortar and then whitewashed.

If stucco is used over pise walls, it is best to place it over some sort of metal lath or wire mesh, and in such a case it is all the more important that the wall be thoroughly dried out before applying the stucco.



Three-room pise cottage built at Aurora, Colorado, by an ex-soldier at a cost $700, including lot, electric lights and running water

Adobe Structures for Earthquake Regions

By J. D. Long[1]

FOLLOWING a severe storm or earthquake it is possible for a critic to enter the devastated area with note pad and camera and secure damaging evidence of any construction material. A hasty survey, one which considers only structural failures and omits a simultaneous and thorough inspection of structures of the material which have weathered the unusual stresses imposed upon them, or a survey which is prejudiced, cannot be expected to yield a complete report of the action of a structural material under these peculiar conditions.

After reading for a period of years news stories which played up structural damage to adobe buildings in these critical testings, I was privileged recently to make a study of earthquake damage to such structures.

Calexico, California, and Mexicali, Mexico, except for the international line dividing them, are in effect one city with approximately 18,000 inhabitants, surrounded by the rich agricultural area of the Imperial Valley.

The San Jacinto fault, a branch of the San Andreas fault which extends through most of California, is said to pass two miles east of the cities, and two others some fifteen or twenty miles west. The former is believed to be the origin of the earthquake which struck the cities at 12:15 A.M. on January 1, 1927, and caused structural damage amounting to nearly $1,000,000. The initial earthquake was quite severe, estimated as lying between intensities eight and nine on the Rossi-Forel scale. It was followed by other severe shocks for a period of twelve hours and minor shocks continued at intervals for over two weeks. Over four hundred separate tremblores were recorded. Damage was centralized in the two cities there being no noticeable damage beyond a ten-mile radius. There was no loss of life or serious human injury. The one fire traceable to this cause was the total destruction by fire of a wood-frame and stucco brewery in Mexicali.

The structures in this region are one and two stories in height, and therefore low enough to be sturdy. Foundation conditions are not of the best because of the deep alluvial soil which is saturated with irrigation water. All types of structures were affected, but it was noticeable that the most damage was traceable to faults of construction and design rather than weakness of the material itself. Practically all of the business buildings of the two cities were damaged, some being injured only by reason of the weakness of the structure alongside. In only a few instances did the noticeable damage to residences extend beyond plaster cracking and chimney damage. Structures of other materials were studied with those of adobe to provide a comparison.

Wood frame construction gave least evidence of severe damage. This was probably due in greatest measure to the light weight and relative elasticity of the structural members and joints. There were a few examples of loosened construction as evidenced in floors which sagged and squeaked under strain and doors and windows which tended to bind. A few crushed roofs resulted from falling brick chimneys. Light weight flues of galvanized iron had been used above the roof line in many of the newer residences to escape this fault.

Common brick was the most common structural material in the commercial section. Failures similar to those occurring in this section were noticed in the one brick residence which was found. Diagonal shear cracks were very common, usually running through the mortar joints; parapet walls were thrown down; and sections of walls were thrown out. In one example of the latter type of failure the rear wall of a section of one-story commercial buildings one-half block long was laid flat. Poor design and the use of a lime mortar of very fine sand accounted for most of these failures.

Reinforced concrete in both integral and skeleton designs came through the ordeal with relatively small damage. Minor cracks, broken windows and parapet wall breaks were most common. In one or two instances walls not properly tied by floor and roof framing bulged out. Filler walls in the skeleton buildings were broken in many instances. The reinforced concrete telephone building suffered considerable damage, the north and south walls being cracked and one of them split away from the east and west walls. As an interesting commentary on the nature of the earthquake damage it was noticed in many instances that the north and south walls were most severely damaged.

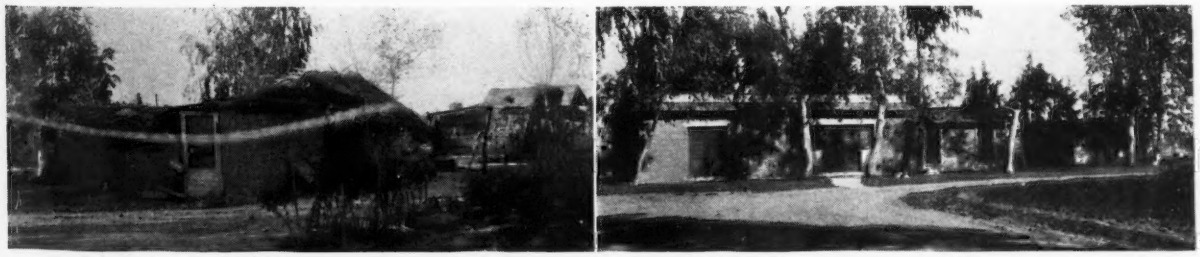
But one structure of precast concrete was found in these cities. This was a low, one-story storehouse in Mexicali which suffered several diagonal shear cracks extending from top to bottom through the cement mortar joints.

Adobe houses of good construction resisted the shake well, more so than would be imagined by a person who knew that the unit strength of the material was less than a fourth that of concrete. Five houses and one native saloon in Mexicali, all of the cheapest construction with no foundation or cross ties, were thrown down or sustained injuries which would require them to be torn down. Two small houses of one or two rooms had split at the corners; a north wall of one was leaning out more than its twelve-inch thickness in its eight feet of height. The owner of each of these houses was proceeding with repairs by building a wood frame inside to support the roof and to tie the adobe walls erect to serve then as a veneer. Of the hundred or more similar houses in this poor district of the city only a few would require partial rebuilding; for the most part they gave no evidences of serious injury. Adobe brick residences costing between $5000 and $20,000 and serving as homes of the professional men and government employees were but very slightly injured.

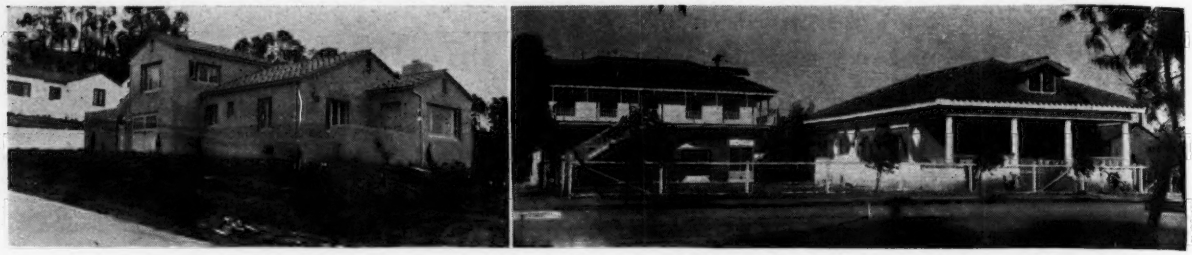
A splendid, one-story, adobe-brick commercial building designed to serve the local electric light company, a bank and three retail stores was caught just before its completion. The adobes forming a parapet wall on the north were partially thrown down, but the major damage was to the east wall where horizontal shear cracks ran along the entire length of wall at the tops and bottoms of the several windows. Two blocks down the street an adobe brick structure and one of common brick furnished an interesting comparison. The brick

[1]Junior agricultural engineer, University of California. Mem. A.S.A.E.

[2]J. de la Fuente, mining engineer, Coahuila, Mexico. Mem. A.S.A.E.



(Left) A typical failure, due to earthquake, of an adobe brick house in Mexicali, Mexico. (Right) An adobe brick ranch house near Calexico, California. The principal earthquake damage here was to the interior plaster



(Left) Adobe brick houses at Santa Barbara, California. The principal earthquake damage to these structures in 1925 was the displacement of some of the roof tile. (Right) An adobe brick residence and apartment house in Calexico, California. The loosened stucco has been removed from the lower walls of the latter but is still clinging in places to the residence walls

parapet wall had been partially thrown down, the parapet of adobe brick had sheared from the side walls to a depth of three or four feet from the top but it was not displaced. Here again it should be noted that lime mortar of poor quality was used for the common brick construction.

The adobe brick school house suffered many shear cracks similar to those noticed in walls of common brick. It was planned to repair this structure by erecting a wood frame inside to carry the roof load and to tie the structure together.

In Calexico four adobe brick structures were noteworthy. One, a large boxlike warehouse at the freight depot, had only parts of two walls standing. This was the most flagrant mismating of structural material and design noticed in that the walls were too high and devoid of sufficient cross bracing for a material low in compression strength. The adobe brick structure housing the local agency of the International Harvester Company had the upper part of the rear wall (a north wall) thrown out. This wall was not tied to the roof framing in any way.

Two well-built adobe residences, one a single-family and the other a two-story apartment, were interesting. In the former a very heavy concrete foundation, good quality adobe brick exterior walls 18 inches thick, one through partition wall of adobe 12 inches thick, a reinforced-concrete bond stone eight inches deep along the tops of all adobe walls, and wood floor and roof framing tying the walls at right angles to the interior cross partition made a very substantial construction. The apartment was similarly constructed and had a reinforced concrete bond stone at the second floor level supporting a concrete porch of cantilever design around the entire exterior. The second story adobe brick walls were 12 inches thick. In both structures, however, a very heavy mass at the top provided in the residence by a heavy tile roof and framing and in the apartment by the heavy mass of the second story walls (the roof was of light framing and roll roofing) gave a pendulum effect which racked the first story walls. Here several shear cracks and a few crushed bricks were in evidence. The cement stucco which had been fastened to the walls with nails driven into the bricks up to one-quarter inch of the head and spaced six inches apart was so badly shattered that it required complete replacement. The second story walls of the apartment, including the stucco, were intact except for two minor shear cracks.

The town of Heber, located some seven miles in a straight line from Calexico, sustained considerable damage to common brick structures including the school house, post office and a garage. A two-story hotel of concrete block which had been damaged by a previous earthquake was rendered unsafe. A hotel across the street with the first story walls of adobe brick and the second story of wood frame gave but one or two minor evidences of the shake. An adobe cottage nearby was undamaged.

Between Heber and Calexico an adobe ranch house was visited in which only the interior plaster had suffered. This structure was one story, with no foundation other than railroad ties laid in a trench, exterior walls of twelve-inch thickness reinforced in every fourth mortar joint with a twelve-inch strip of woven wire lapped at the corners, and a flat roof of roll roofing. A shear crack was barely discernible in the center of the north wall. This structure provides a particularly noteworthy example as it so aptly fulfills its requirements as a ranch home for this locality and climate.

Following the inspection of structures in the Calexico region a visit was made to Santa Barbara where data relative to the effects of the earthquake a year and a half ago was secured. It was learned here that adobe buildings of recent construction were but very slightly damaged. The older adobes, many of which were severely damaged, were the ones which had attracted comment and condemnation of the material. This selective action was due probably to two reasons: the sturdier design of the newer buildings and their restriction to small compact residences rather than more monumental structures; and the location in the main of the new adobes on higher ground and a better foundation strata than the structures in the commercial district which were on an alluvial soil base. One writer has further suggested that in the older structures the walls had become bone dry and hence were more readily pulverized by the stresses they encountered. I cannot concur in this belief.

From these surveys certain design data for adobe structures in earthquake regions might be compiled as follows:

1. The plan of the building should preferably be compact and rectangular. Since it has been noted that the point of maximum damage in high buildings is at one-third or one-fourth their height (the point of maximum strain in a cantilever beam), low height, wide space structures minimize the damaging effect of the oscillations.

2. A substantial, one-piece foundation is necessary and is best provided by monolithic concrete laid on the densest subgrade available.

3. Considering that adobe bricks have a maximum average compressive strength of 500 pounds to the square inch, it is advisable that in one story construction exterior walls be not less than 12 inches and non-bearing partition walls 8 inches in thickness. For two-story construction these thicknesses may be used for the second story walls and thicknesses of 18 and 12 inches should be the minimum for the exterior and interior walls of the first story. Second stories of light wood framing are to be preferred.

4. Mud mortar of such consistency and composition that it will dry to a hard, dense mass is suitable for adobe construction. Lime and cement mortars may be used.

5. Integral reinforcement of the wall is advisable, woven wire fencing in every fourth or fifth horizontal mortar joint and lapped at the corners probably being as good as can be secured. One variation of this method would be to use a six-foot width of one-inch mesh, No. 18 gauge poultry fencing. Putting this in every sixth mortar joint with edges extending evenly on each side to turn down and staple against the wall will provide a continuous reinforcing for plaster and stucco. Vertical reinforcement is not necessary and usually forms a plane of weakness in the wall. It should not be used unless it is designed as a frame to carry the roof loads with the adobe brick serving as filler walls.

6. Adobe brick interior walls should be mounted on a foundation integral with the exterior wall foundation and should be similarly reinforced.

7. Partition walls of materials other than adobe should be of light construction to avoid such rigidity as might crush or displace the adobe bearing walls in case of an earthquake.

8. A continuous reinforced-concrete bond stone of six-inch minimum depth should be placed at the top of all adobe walls. Such a reinforcement ties the wall at its most vulnerable point and provides a more secure roof anchor.

9. Ceilings of wall board, lumber or sheet metal are usual-

ly preferable to those of plaster as there is less danger of them dropping from position.

10. The roof truss should be so designed as to impart only compression loads to the bearing walls. Roofs should be of light weight.

11. Roof and floor cross-pieces, or members at right angles to them, should provide a cross-tie for each wall at each ceiling line.

12. A protective covering should be used on the exterior to prevent excessive weathering, particularly at the ground line.

I believe from my inspection of numerous adobe structures which survived the Santa Barbara and Imperial Valley earthquakes with no, or but minor, damage, that such construction can be made proof against any but the most severe physical shocks. Unit for unit I believe that such buildings of good design and construction have proven as practical and as suitable for use in these regions as some of the materials and designs now used there for light structures. For the latter region particularly I believe adobe has advantages of temperature control which warrant a serious consideration of its use in most small dwellings. Granting that it is weaker and more subject to earthquake damage than the more standard materials, many persons who intelligently use adobe will willingly accept certain minor damage after a period of years lying between earthquakes to secure the added advantages.

Further evidence of the resistance to shock shown by this material is contained in a letter recently received from J. de la Fuente[2], who states that, in tests conducted in Mexico City, adobe has proven superior to certain other standard construction materials when subjected to dynamite explosion and rifle firing. In any use of adobe, however, it is only common sense to remember that it has a lower unit strength than any of the standard materials and that consequently certain precautions must be met. In addition to the design features which have been listed, such precautions will include honest and intelligent workmanship.

In conclusion, I desire to express my appreciation of the services rendered by the many cooperators in this survey, particularly Joaquin Palencia, engineer of the northern district of Lower California, R. Manuel, building inspector of Calexico, and L. L. Pope, building inspector of Santa Barbara.

Rotary Tiller Combined With Tractor Drivewheel

By E. G. McKibben[1]

AN INTERESTING and fundamentally new idea in power tillage has been patented and is being developed by a California manufacturer-rancher[2]. The tillage elements (truly spade lugs) are attached directly to the wheels of the tractor, thus eliminating the usual power losses due to the soil transmission of power.

Although, as indicated by the photograph, this machine is still in the development stage, the materials and construction used, results accomplished, and possible advantages and disadvantages should be of interest to any agricultural engineer who is concerned with tillage problems.

The spades (1)[3] are steel casting and 5 inches high. The spade springs (2) are made of 5/16-inch by 2-inch automobile spring stock and are 18 inches long. The wheels are 18 inches in diameter and 24 inches wide. When the springs are flexed, as at the bottom of the wheel, the distance between spades is about 6 inches.

The action of the spades is quite simple and apparently effective. Each of the wheels is power driven. When the spades first strike the ground the springs are flexed, (a) and then as the weight of the tractor is placed upon them they are forced into the ground (b). As the weight of the tractor is removed from the spades and they start to leave the ground the bending stress is removed from the springs and the resulting reaction further loosens that portion of the soil which has been broken loose by the penetration of the spades (c).

The machine shown was powered with a Ford automobile engine with an overall gear ratio of 30-to-1 and tilled a strip 4 feet wide. This engine had sufficient power to propel the machine up the grade shown in the photograph at 1.75 miles per hour.

It seems entirely possible that some development of this idea could be used for almost all types of tillage except subsoiling and deep plowing. It may be possible to pull a standard moldboard plow behind such a machine and thus do in one operation the equivalent of discing and plowing with very little more power than is now taken for plowing. With the wide dimension of the spade points rotated 90 degrees, this might prove to be an excellent machine for rejuvenating old alfalfa fields.

A preliminary analysis of this machine and its operation indicates certain inherent advantages and disadvantages, namely:

Possible Advantages

1. It will eliminate large power losses due to our present method of soil transmission of the power required for tillage.
2. If it can be reversed, it should be possible to till more nearly all of the soil in the corners than with most tillage tools.
3. It does not pulverize the soil excessively as many rotary tillers do.
4. It does not waste power by giving an excessive but valueless velocity to the soil particles.
5. There may be less tendency to form a so-called plow sole.

Possible Disadvantages

1. The initial and replacement costs of the spade springs may prove to be excessive.
2. In its present form it may be difficult to reverse this machine without breakage, due to the action of the spades and springs when the motion of the wheels is reversed.
3. It probably will not be possible to invert completely a layer of the soil and thus bury a cover crop as is done with a plow.
4. There may be a greater tendency to pick up and distribute the roots of noxious weeds.

Of course, as the commercial development of this machine progresses other advantages and disadvantages may appear. These, with those listed above, will determine the ultimate success or failure of the idea.

[1]Junior agricultural engineer, University of California. Mem. A.S.A.E.

[2]O. M. Bullock of Oakland, California.

[3]Figures and letters in parenthesis refer to accompanying picture.

Experimental model of a rotary tiller with spading and drive members combined

Research On Wood Preservatives

By Harold T. Barr[1]

MAXIMUM service is being obtained from a very small percentage of wood used on American farms, due to improper protection from the elements which cause decay.

What is the cause and prevention of decay?

I. Wood destroying fungi cause the decay in wood. They are plants which grow in the wood and require water for growth. Keeping the wood dry would prevent decay

II. Poisoning the wood prevents the growth of fungi. Wood preservatives are fungus poisons and the object of their use is to poison the food on which the fungi feed

III. Some species are more resistant to decay as they contain a natural preservative

IV. Varnish and paint are not effective fungicides. But they have a wide range of use as a protective coating to prevent warping, weathering and frequent wettings from rains

The following factors have a very definite bearing on the amount of treated material being used:

1. Lumber yards do not handle treated materials
2. Farm treating may be considered too expensive and requires too much labor
3. Lack of information by agricultural people as to the saving that may be effected by treating
4. Creosote treatment has the disadvantage of a rather high price and inability to use light paints over it. Yet it is the only preservative used to any degree

For these reasons several agencies have been seeking a method of effective preservation at low cost, by the use of water-soluble salts. Zinc chloride is the only water-soluble salt that is used in a commercial quantity, 33 million pounds being used in 1924.

A study of available information on preservative treatments of farm timber indicates the following facts:

1. The life of post material can be increased economically by a preservative treatment
2. There is a demand for a cheaper and easier method of treatment than by using creosote
3. Zinc chloride will give a satisfactory increase in life at less cost, with possibilities of a much easier and cheaper treating process
4. Sodium fluoride may give a satisfactory increase at less cost than creosote
5. Copper sulphate and mercuric chloride have been tried, but can not be used in a metal vat or cylinder and they corrode wire and staples
6. Patented salts composed largely of zinc chloride or sodium fluoride have given satisfactory results in Europe

In order to obtain definite information on the various preservative agencies in comparison with creosote and to obtain information directly applicable to posts, the agricultural engineering department of the Arkansas Agricultural Experiment Station has in progress a research project on wood preservation. This project has been under way for four years. Following is a statement of the method and objectives with a brief summary of the work done to date.

The project "Durability of Posts and Methods of Preservative Treatment" has the following objectives:

1. To determine the durability and comparative economy of available post material by means of service test
2. To develop a method of securing optimum penetration of preservatives
3. To determine the comparative value and cost of various preservatives for wood posts

The plan of procedure is divided as follows:

1. Service tests in the university vineyard with untreated oak, creosoted oak post, pressure process Long-Bell southern pine; seven types of steel posts as to shape, painting, and galvanizing; and cement posts. Each post is tagged with an aluminum tag and inspected annually

2. Penetration tests were next undertaken, using the following methods of treatments and preservatives:

Three specimens each of southern yellow pine and red oak 1½ in. square by 36 in. long of uniform grain, free from knots, thoroughly seasoned and of small variation in weight were used for each test.

Graph I shows the rate of absorption and that it is very small after 12 hours. Several commercial plants are treating with from 0.3 to 0.5 lbs. of dry zinc chloride per cubic foot. Not enough data is at hand to show whether this is sufficient or not. If it is a steeping process, it is cheaper and easier for farm use on soft woods; but it is better to use a 5 or 7.5 per cent solution than a 2.5 per cent solution. The following table also shows absorption by hot and cold treatments.

Dry Zinc Chloride

7.5%	1.810 lb.—1 hr. at 160° plus 70° overnight,	pine
	0.499 lb.—1 hr. at 160° plus 70° overnight,	oak
	2.490 lb.—2 hr. at 160° plus 70° overnight,	pine
	0.599 lb.—2 hr. at 160° plus 70° overnight,	oak
5%	0.892 lb.—1 hr. at 165° plus 70° overnight,	pine
	0.220 lb.—1 hr. at 165° plus 70° overnight,	oak
	0.863 lb.—2 hr. at 165° plus 70° overnight,	pine
	0.278 lb.—2 hr. at 165° plus 70° overnight,	oak
2.5%	0.611 lb.—1 hr. at 160° plus 70° overnight,	pine
	0.187 lb.—1 hr. at 160° plus 70° overnight,	oak
	0.544 lb.—2 hr. at 160° plus 70° overnight,	pine
	0.145 lb.—2 hr. at 160° plus 70° overnight,	oak

Sodium fluoride was used in a 2.5 and 3.5 per cent solution for periods of 12 and 24 hours per inch in a steeping bath and 2 hours and 4 hours per inch in hot bath and cold overnight. (Both sodium fluoride solution and refuse cylinder oil were used in cold bath over night.) A penetration was obtained as follows:

Sodium Fluoride

2.5% solution

Kind	12 hr. per in. steeping	24 hr. per in. steeping	2 hr. hot per in. plus cold overnight	2 hr. hot per in. plus refuse cylinder oil Dry.	S. Fl.	Oil	4 hr. hotbath plus cold overnight
Oak	0.075	0.100	0.286	0.053		1.19	0.244
Pine	0.096	0.335	0.146	0.349		7.37	0.802

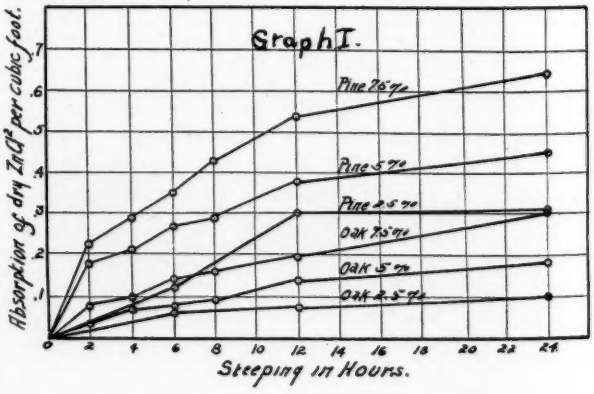
3.5% Solution

	Steeping 12 hr. per in.	24 hr. per in.	2 hour hot per inch plus cold overnight
Oak	.097	.152	.171
Pine	.239	.282	.833

The above tables are presented as a progress report and not as a final report in their respective fields.

To get a service test which will show the amount of the various preservatives needed for the most economical increase in life, 330 specimens were set two feet in the ground and one foot above so as to cover the range of the most rapid decay. The soil selected for the test plot is a black sandy loam, situated on low ground remaining damp a large part of the time.

It is my belief, backed by data from many sources, that there is a large field for some treatments and preservatives which will give a cheap and easy method of treatment and at the same time greatly prolong the life of farm timber for all purposes.



[1]Instructor of Agricultural Engineering, University of Arkansas, Jun. Mem. A.S.A.E.

The Effect of Growth Upon the Capacity of Drainage Ditches*

By C. E. Ramser[1]

ANY obstruction in a drainage ditch retards the velocity of the water and thereby tends to defeat the object for which the ditch was intended. Vegetation is the most common form of obstruction in drainage ditches. Ditches badly choked up with growth consisting of weeds, tall grass, vines, bushes, sprouts, and small trees are of common occurrence in every section of the country. The generally bad condition of ditches throughout the country would naturally lead one to conclude that few engineers or officials of drainage districts realize that there is a very appreciable difference in the discharge capacity of a cleared and an uncleared channel.

For the purpose of obtaining information on the relative capacities of cleared and uncleared channels, the necessary field measurements were made on channels in the states of Missouri, Mississippi, Arkansas and Illinois by the author and his associates in the Division of Agricultural Engineering of the U. S. Department of Agriculture. In many instances these measurements were made on the same course of channel before and after clearing or before and after the growth of vegetation so that a direct comparison could be made of the discharge capacities. In other instances the capacities of the channels in bad conditions were compared with channels in good condition in the same vicinity.

These measurements consisted of obatining the discharge, average cross-sectional area and slope of the water surface of a course of channel and computing therefrom the roughness coefficient, n, in Kutter's formula. The term "n" is an index of the condition of the channel, the larger the value of n the worse the condition of the channel and the smaller its discharge capacity. It is a measure of all conditions in a channel that tend to retard the flow such as irregularities in cross-section, vegetation and other obstructions. However, in these experiments the difference in the value of n for the same channel before and after clearing, or before and after growth of vegetataion, can be attributed to the vegetation alone since other conditions affecting the value of n remained the same.

In the experimental determination of the value of n in Kutter's formula.

$$C = \frac{41.6 + \frac{1.811}{n} + \frac{0.00281}{S}}{1 + \left(41.6 + \frac{0.00281}{S}\right)\frac{n}{\sqrt{R}}}$$

The coefficient C is first obtained from Chezy's formula,

$$V = C\sqrt{RS}$$

and then the value of n by solving for n in Kutter's formula.

In solving Chezy's formula for C the following terms must be known: V, the mean velocity along the slope course; R, the mean hydraulic radius along the slope course, and S, the mean slope of the water surface along the slope course.

The data required for computing these values were obtained by field measurements. The discharge was measured with a current meter and the mean velocity, V, was obtained by dividing the discharge by the mean cross-sectional area along the slope course.

The results of the measurements, accompanied also by photographs illustrating the condition of the channels at the time the measurements were made, are given in the following paragraphs:

Old Town Creek Ditch near Tupelo, Mississippi. A view of this channel taken during the year 1913 before it was cleared is shown in Fig 1. One side slope of the channel and part of the bottom were practically covered with small saplings, brush and cane. The other side slope was compara tively free from vegetation. The average value of n at near bankful stage for this channel was about 0.045. A view of this same course of channel taken during the year 1914 after the growth had been cleared out is shown in Fig. 2. The average value of n obtained for the cleared channel at near bankful stage was 0.030. Using these values of n for the same stage for the two conditions of channel, it was found that the cleared channel had a discharge capacity about 45 per cent greater than the uncleared. This is a very appreciable increase when considering that only one side slope of the channel was covered with a rather light growth of vegetation.

Ditch No. 1 of the Little River Drainage District. In Figs. 3 and 4 are shown views of the same course of this channel with and without a growth of willows. This channel is usually cleared every two years. The rather thick willow growth shown in Fig. 4 is a little over one year old. Values of n obtained for the two conditions of channel at about bankful stage were 0.0315 and 0.0732, cleared and uncleared, respectively. From these measurements it was found that the capacity of the channel could be about doubled by clearing out the willows. Referring to Fig. 4 it is seen that the willows obstruct practically the entire channel with the exception of a narrow strip down the center. Some silting occurred in this channel due mainly to the presence of vegetation.

Cummins Lake Ditch near Gould, Arkansas. In Figs. 5, 6 and 7 are shown three views of the same course of the Cummins Lake Ditch taken at different times. The first was taken during March 1925 shortly after the construction of the ditch when there were only a few dead weeds in the channel; the second was taken about one year later during March 1926 when a thick growth of willows almost completely filled the channel; and the third was taken a few months

Fig. 1. (Left) Old Town Creek dredged ditch near Tupelo, Miss., before clearing in 1913. Fig. 2. (Right) The same ditch afer clearing in 1914

*Paper presented at the 21st annual meeting of the American Society of Agricultural Engineers, at University Farm, St. Paul, Minn., June, 1927. Contributed by the Reclamation Division.

[1]Drainage engineer, U. S. Department of Agriculture. Mem. A.S.A.E.

Fig. 3. (Left) Ditch No. 1 of the Little River drainage district near Chaffee, Mo., April, 1923, before the growth of willows. Fig. 4 (Right) The same ditch in December, 1925, showing the growth of willows

later than the second during June 1926 when the willows were in full leaf. Values of n obtained for the conditions of channel shown in Figs. 6 and 7 were 0.052 and 0.070, respectively. Assuming that the value of n for the practically cleared condition of the ditch in Fig. 5 was about 0.0325, it is found that for a bankful stage of the channel the capacity before the appearance of the willow growth was over 50 per cent greater than it was for the growth without foliage as shown in Fig. 6 and about 100 per cent greater or about double the capacity for the growth of willows in full leaf as shown in Fig. 7. These measurements apparently indicate that drainage ditches should be cleared out every year in order that they be maintained in a comparatively high state of efficiency. This ditch and Ditch No. 1 of the Little River Drainage District become almost dry in the summer time, which it is believed accounts for the rapid growth of willows as compared with ditches where there is an appreciable flow all the year. An examination of the bottom of this ditch showed that a certain amount of silting had taken place which was due no doubt largely to the presence of vegetation. As a general rule where vegetation is permitted to remain in a ditch over a long period of years the cross-section of the ditch is greatly reduced in size by the accumulation of silt which often necessitates the redredging of the channel. This of course is especially true where the ditch drains a somewhat rolling and hilly watershed.

Ditch No. 18 of the Cypress Creek Drainage District. A view of this ditch is shown in Fig. 8. This ditch has never been cleared since it was dredged. Practically the entire channel is filled with a growth of trees, consisting principally of willows and cotton wood about eight years old. A value of n of 0.1315 was obtained for a near bankful stage which is the highest value for all ditches where measurements were made. This measurement was made when there was a heavy growth of foliage on the trees, and it was impossible to see any appreciable distance along the channel. It was found that the capacity of this ditch is only about one-fourth of what it would be if it were cleared out and that a cleared ditch with about one-third its cross-sectional area would have the same discharge capacity. The capacity of this ditch in its present condition is entirely too small to provide satisfactory drainage for the land in its watershed. Overflows generally occur after every heavy rain.

Lake Fork Special Ditch near Bement, Illinois. Measurements of the flow in this channel were made before and after it was cleared. The vegetation in the channel consisted principally of bushy willows. Views of the channel before clearing are shown in Figs. 9 and 10, the first with the growth in full leaf was taken during the summer of 1924 and the other with no foliage was taken in the spring of 1925. The view in Fig. 11 was taken shortly after the channel was cleared. A value of n of 0.085 was obtained for the channel with growth in full leaf and 0.0324 for the channel after the growth was cleared out. It was found that the channel carried about 75 per cent more water after being cleared out. The cost of clearing out this channel was insignificant as compared with the losses sustained by the farmers due to the tardy removal of the excess water after every heavy rain.

West Branch of the Salt Fork Ditch near Urbana, Illinois. A view of the west branch of the Salt Fork Ditch is shown in Fig. 12. The vegetation in this ditch consists of a growth of small trees of different varieties on the side slopes, the bottom being quite wide with practically no growth. A value of n of 0.067 was obtained for this ditch as shown in the

Fig. 8. Ditch No. 18 the Cypress Creek drainage district near McGehee, Ark., March, 1925

Fig. 5. (Left) Cummins Lake ditch near Gould, Ark., March, 1925, before the growth of willows. Fig. 6. (Middle) Willows without foliage. Fig. 7. (Right) The same ditch in June, 1926, showing growth of willows with foliage

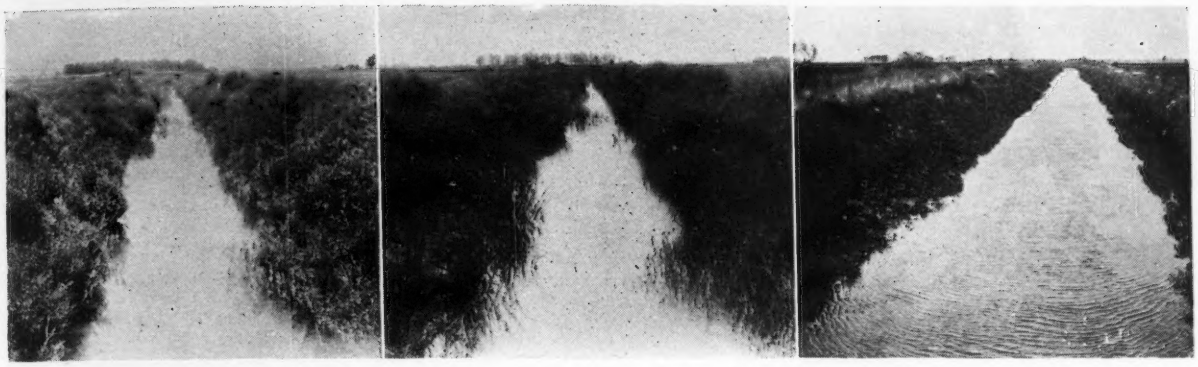


Fig. 9. (Left) Lake Fork special ditch near Bement, Ill., before clearing, July, 1924. Fig. 10. (Middle) The same ditch before clearing, April, 1925. Fig. 11. (Right) The same ditch after clearing, May, 1926

figure when there was no foliage on the trees. With foliage the value would have been considerably higher judging from values obtained for other channels with growth with and without foliage. This channel has never been cleared out since it was dredged. Clearing it would practically double its capacity.

Kaskaskia Mutual Ditch near Bondville, Illinois. This ditch has never been cleared out since it was dredged as one would be led to conclude judging from the size of the trees in the channel shown in Fig. 13. This view was taken in the spring before the appearance of foliage on the trees. In Fig. 14 is a view of the same course of channel taken when the trees were in full leaf. The heavy foliage practically obstructs the view of the channel. A value of n of 0.101 was obtained for this ditch for the condition shown in Fig. 14. Computing the capacity of this ditch with the assumption that a value of n of 0.030 would apply if it were cleared it was found that it would provide for the removal of three times as much water after being cleared. Ditches of this sort afford extremely poor drainage. Not fully realizing the cause, landowners will often have such ditches dug larger when, if the growth were simply removed at a much less cost, satisfactory drainage would prevail.

Fig. 12. West branch of the Salt Fork ditch near Urbana, Ill., April, 1925

Main Diversion Floodway of the Little River Drainage District. This floodway is about 1100 feet wide between levees and drains an area of over 1100 square miles of hilly topography. Vegetation grows very rapidly in this floodway, and it was desired to know what effect the growth would have upon the discharge capacity of the floodway since a reduction in its capacity with the possibility of the overtopping of the levees would have proved disastrous to the drainage and flood control project.

Measurements were made on two courses of this floodway. Everything was cleared from one course except the stumps and a growth of dry slough grass which did not exceed more than 3 or 4 inches in height. A view of this course is shown in Fig. 15. The other course was left in an uncleared condition as shown in Fig. 16. The floodway had been cleared about three or four years before this view was taken since which time no clearing had been done. The growth in the floodway consisted of willows and sprouts from the stumps. There was very little undergrowth such as vines or weeds and the condition as regards grass and stumps was practically similar to that of the cleared course. The average value of n obtained for the cleared course was 0.046 for depths of water ranging from 4.4 to 5.4 feet and the average value for the uncleared course was 0.0758 for depths of water of 4.5 and 4.9 feet. Using these values and computing the capacities for cleared and uncleared conditions and for the same stage it was found that clearing this floodway would increase its capacity about 60 per cent.

The measurements in the cleared course of the floodway were made about a month after the floodway was cleared, so in the practical application of the results it should be remembered that the condition of the cleared course was practically as good as ever could be expected unless, of course, the stumps were removed.

Fig. 13. (Left) View of the Kaskaskia Mutual ditch near Bondville, Ill., April, 1925. Fig. 14. (Right) The same ditch in July, 1924

Fig. 15. (Left) Cleared course of the main diversion floodway of the Little River drainage district near Cape Girardeau, Mo. Fig. 16. (Right) Uncleared course of the same floodway

The importance of systematic maintenance of floodways cannot be overemphasized. Clearing of floodways annually would be required to keep them in good condition unless some other method is employed to prevent the rapid growth of sprouts at a reasonable cost. Cultivation and pasturing has been employed quite successfully in some instances. One method quite extensively used in clearing land in Arkansas to prevent the growth of sprouts is to poison the trees.

St. Francis River Floodway near Marked Tree, Arkansas. This floodway has a maximum depth of flow of about 10 feet and has a width between levees of 2500 feet. It is, I believe, the widest artificial floodway in the United States. The floodway is covered with practically virgin timber, there having been very little timber ever cut off. A view taken in the floodway is shown in Fig. 17. In addition to obtaining data for general use for such a floodway it was desired to know what effect upon the capacity clearing the floodway would have. Measurements of the discharge, the slope of the water surface, and the cross-sectional area at the gaging station midway of the slope course have been made. The cross-sectional area varies somewhat along the slope course which is 8000 feet long. It is intended to obtain measurements of the cross-section at intervals of 1000 feet along the slope course before the final computations for values of n are made. A value of n of about 0.150 was obtained by using the single cross-sectional area at the gaging station. It is believed this value will be subject to a change of 0.01 more or less when all cross sections enter into the computations. The discharge capacity of this floodway was computed using a value of n of 0.046, the value obtained for the cleared floodway of the Little River Drainage District from which it was found that the capacity of the St. Francis River floodway could be nearly tripled by clearing off the timber and undergrowth.

The results of the measurements presented in this paper show conclusively that the usefulness of a drainage channel is greatly impaired by the growth of vegetation. In most localities drainage channels should be cleared out annually if maintained

Fig. 17. View of a portion of the St. Francis River floodway near Marked Tree, Ark.

in a state of comparatively high efficiency. The expense of clearing out a channel is in most cases trivial as compared with the crop losses sustained as a result of one moderate overflow. Vegetation in a ditch often causes appreciable silting which sometimes requires the redredging of the ditch at great expense as compared with the smaller cost of systematic maintenance. The presence of vegetation in a drainage channel indicates either that the landowner is not deriving the full benefit from drainage for which the ditch was intended, or if he is enjoying this benefit then the ditch was made needlessly large at the expense of the landowner's pocketbook.

(AUTHOR'S NOTE: The results of the foregoing measurements and other additional measurements will be published in detail sometime in the future and can be obtained upon application to S. H. McCrory, chief, Division of Agricultural Engineering, U. S. Department of Agriculture, Washington, D. C.

The reclamation of waste areas and the conservation of soil resources constitute one of the principal branches of agricultural-engineering activity. This entire field—that is, its engineering and economic aspects—is comprehended in the scope of the Reclamation Division of the American Society of Agricultural Engineers. This Division has established a point of contact for engineers in this field that is proving exceeding helpful to them. The constantly increasing attendance at and growing interest in the meetings of the Division is evidence that it is serving a real need.

Observations on Electric Brooding

By J. E. Dougherty[1]

ELECTRICITY as a source of heat for brooding chicks has proven very popular with poultry keepers in California because of its convenience. Only two objections seem to stand in the way of it being used much more extensively for brooding and incubation than it is at present. These are dependability of supply and high cost per kilowatt-hour. When the power companies reduce the liability of interruption to the supply of current from a major to a minor hazard and reduce the net cost to compare favorably with other sources of heat, electric heating will probably displace other methods for brooders and incubators wherever it is obtainable by poultry keepers.

Electric heating differs from other methods in two very important ways: (1) The air is not vitiated by the combustion of fuel and (2) the heat can be turned off and on as frequently as is necessary to maintain any given temperature.

Since electric heating does not vitiate the air one might suppose that its use for brooding would simplify the problem of obtaining adequate ventilation, and it should do so, if properly applied. But most operators of electric brooders have heretofore made the grave error of restricting the ventilation to a point much below the optimum in order to hold down the consumption of power, overlooking the fact that in saving electricity they were injuring the chicks by lowering their vitality and checking their growth. Chicks give off carbon dioxide and moisture in breathing, and considerable moisture as well as unhealthful fumes comes from the droppings. Unless there is sufficient ventilation of the brooder to carry away the contaminated air and replace it with fresh air, the atmosphere under the hover at night soon becomes not only dangerously depleted of oxygen but so heavily charged with water vapor that it will not hold it all and the excess condenses on the cooler surfaces. Under such conditions the chicks are said to "sweat," because they feel damp to the hand. The floor becomes quite moist and the lower edge of the curtain, particularly if it be made of table oilcloth, may accumulate beads of moisture. This is a decidedly unhealthful condition that can be readily remedied by increasing the circulation of air through the hover.

Probably the most feasible means of ventilating a brooder is by diffusion and the effectiveness of such ventilation will depend upon the size of the ventilation openings and upon the number and size of the chicks that are under the hover contaminating the air. A brooder holding a large number of chicks should, therefore, be more open than one holding a small number so that the heat units consumed per chick are practically the same no matter what the number of chicks under the hover may be.

A round or square hover with a curtain all around is more readily ventilated than a box hover open on only one or two sides as there is more open space through which air can pass in and out. But even in hovers with curtains all around, the ventilation may become deficient as the chicks grow, if the canopy is not raised a little higher each week to increase the circulation of air under it. The bottom of the curtain should hang from ½ to 1 in. above the floor when the chicks are first put in and should be raised approximately ½ inch per week as the chicks grow. Whether it is ½ or 1 in. above the floor at first and just how rapidly it is raised will depend upon the coldness of the weather. The cooler the weather the greater will be the difference in temperature between the air in the hover and the air outside the hover, and the rate of air movement in and out of the hover will be found to be directly proportional to the amount of this difference, other things being equal. In autumn, winter and early spring weather, therefore, the curtain should hang closer to the floor at first and be raised less rapidly than in the warmer weather of late spring.

Electric brooding has suffered from an overzealous effort to restrict power consumption without a due appreciation of the effect on ventilation. Power consumption can only be held down by restricting ventilation (assuming the brooder to be well designed and effectively insulated); the more air that circulates through the hover the more heat is carried out and the more power is required to maintain a given temperature.

On the other hand, brooder design can be carried to extremes, in so far as power consumption is concerned, in the attempt to make ventilation proof against ignorance and mishandling. The so-called radiant brooder is an example. With this brooder no curtain is used, and the canopy is equipped with legs that hold it high enough above the floor so that there will always be an abundant flow of air under it. But the power consumption is very heavy due, principally, to the absence of a curtain. Experience with such brooders compels the conclusion, however, that the ultimate practical solution of the problem of ventilation and power consumption in electric brooders rests upon a proper balance between these two factors. As I see it at the present moment, this balance can be most effectively accomplished by the use of a brooder with a curtain all around and the proper adjustment of the height of this curtain from week to week to insure good ventilation under the canopy. The economic desirability of brooding chicks in fairly large groups, the natural habit of chicks so brooded to sleep in very close contact with each other until they learn to roost, and their rapid rate of growth are factors which necessitate adequate ventilation adjustments of the brooder from week to week, if a satisfactory balance between ventilation and power consumption is to be maintained. To this end a poultry keeper must either possess a working knowledge of the principles involved and enough good common sense and experience to enable him to apply them effectively or, if an amateur, be intelligent enough to appreciate the necessity of closely adhering to the instructions of those who have had wide experience and success with the brooders concerned until experience and knowledge have been obtained.

A simple application of the principles of electric heating and of ventilation to the brooding of chicks is shown in Figs. 1 and 2. This brooder is made of wood, is 48 in. square and has a capacity of 300 chicks on the basis of 7 sq. in. of floor space per chick—it may, however, be made 54 in. square if desired. The top is insulated (E, Fig. 1) with Celotex or other good insulating wallboard covered with a thin sheet of asbestos. The latter can be held in place with narrow strips of light galvanized iron.

The temperature in this brooder is controlled by a thermostatic electric breaker. The expansion and contraction of an ether wafer as the temperature rises above or falls below the point at which the breaker is set, closes or opens the circuit and will hold the temperature within one degree. A dependable breaker designed especially for brooders must be used. Make shifts are never satisfactory. The breaker and heating units are the vital parts of an electric brooder and unless these are right, trouble will result.

The ether wafer should be installed as high as possible to prevent chicks getting against it and affecting the regulation. The thermometer may be placed on a stand and slipped underneath one side of the hover or a hole for it bored in the top. This hole should be one foot in from the edge of the hover and the thermometer should hang with the bulb 2 in. above the floor. In fact two thermometers close together would be better than one. The second thermometer should be hung with the bulb 5 in. above the floor and the difference in temperature between the two thermometers noted when running the hover empty. After the chicks are a week old they are likely to get against the bulb of the low hung thermometer at night and the heat of their bodies will run the thermometer reading up higher than the temperature of the air under the hover. When this happens the air temperature of the hover can be checked by the high hung thermometer.

Three porcelain cleat receptacles on top of the hover (for

[1]Division of poultry husbandry, University of California.

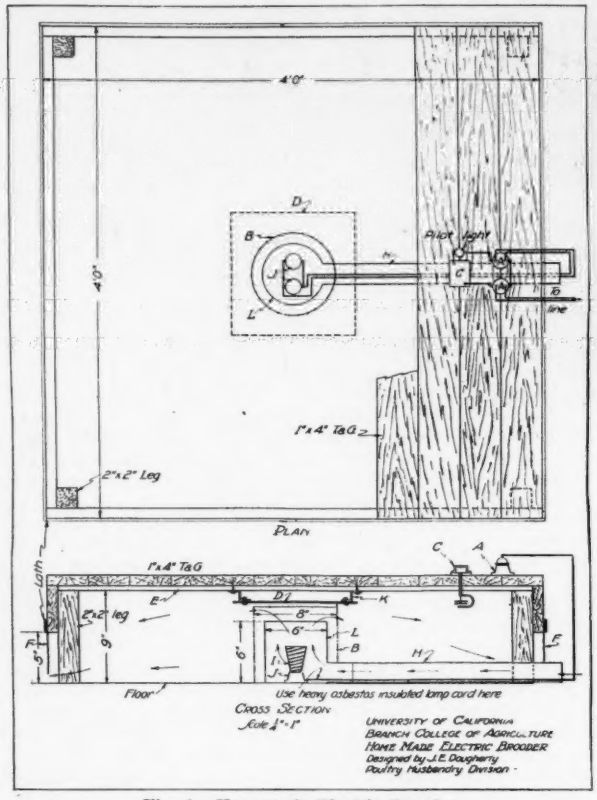


Fig. 1. Homemade Electric Brooder

(A) Porcelain cleat receptacle with plug screwed into it. The plus terminals are shown inside and the cleat receptacle terminals outside
(B) Cylinder of ½-inch mesh hardware cloth 8 inches in diameter and 6 ½ inches high which is placed around the 6-inch can containing the heating elements to keep the chicks away from the hot surface of the can
(C) Thermostatic electric breaker which automatically turns the electricity on and off and regulates the temperature
(D) 24-guage galvanized iron shield 10 inches square to protect top of hover from being scorched
(E) Celotex or other insulating wallboard covered with a thin sheet of asbestos held in place by narrow strips of light sheet iron
(F) Curtain made of table oilcloth and containing 2-inch slits every three inches. Bottom of curtains should be 1 inch above floor
(G) Lath used to hold curtain in place
(H) 2-inch rain conductor pipe used as fresh air intake
(I) 300-watt nonglowing heating elements connected in parallel
(J) Porcelain cleat receptacles into which heating elements screw
(K) Supporting bracket one inch wide made of folded 24-guage sheet iron or of light weight bar iron
(L) Galvanized iron can containing heating units. Porcelain cleat recepticles are bolted to bottom of can

pilot light and connecting plugs, Fig. 1) and the electric breaker should be placed as close together as possible and protected from the chicks with a removable cover through which the glow of the pilot light can be seen when lighted. The chicks will get on the top of the hover as they get older, and its flat top it will be found to be a very convenient place for the mash hoppers and water vessels in order to keep them out of the litter.

The can containing the heating elements, the piece of 2-in. rain conductor pipe used as a fresh air duct and the 12-in. square galvanized heat reflector can be made at the local tin shop. The porcelain cleat receptacles, cord and plugs can be obtained at any electric store. The heating units which may be more difficult to obtain, for they must be of the screw socket type to screw into the two porcelain cleat receptacles in the can, have a capacity of 300 watts each and burn black. Screw socket heating units were originally designed for use in radiant room heaters and to burn with a very bright glow at approximately 600 watts. These are carried in stock by electric supply stores. However, a glowing unit cannot be successfully used in the closely confined conditions under a hover of this kind as it would burn out.

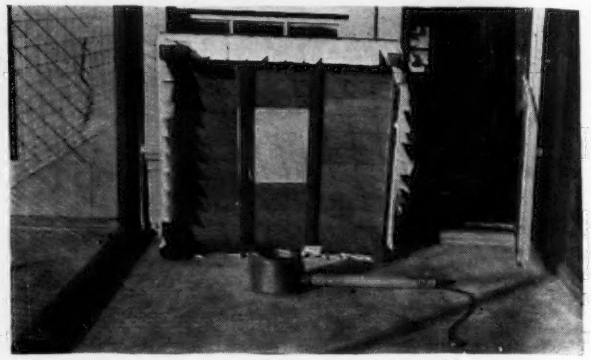


Fig. 2. Homemade electric brooder with hover raised to show heater and fresh air duct with cord from heating elements running through it. The hover shown is an early model and has been much improved as shown in Fig. 1

Therefore, the glowing heating unit regularly stocked must be rewound with resistance wire which will have a capacity of 300 watts and burn black or with a very dull glow. This is easily done by any electric shop stocking the required resistance wire and equipped with a lathe to wind it into a coil. When the new coil is made, the old coil is slipped off and replaced with the new one. It is less expensive, at present, to rewind a stock heating unit than to obtain especially wound units from the factory, unless a large number are ordered, as resistance wire is quite cheap and the coils can be made quickly. It is to be anticipated, however, that progressive manufacturers will soon be catering to the rapidly growing demand for nonglowing heating units of this type. Thirty feet of No. 23 Calido or Nichrome resistance wire wound in a coil on a screw socket heating unit should consume 300 watts per hour on a 110-volt circuit and burn black or with a very dull glow.

Sand or a ¼-in. layer of asbestos should be placed in the bottom of the can containing the heating units for insulation. This can has a bottom but no top. The air duct is crimped on one end to fit into the short intake connection in the side of the can (Fig. 2) and a piece of ½-in. mesh hardware cloth bent to form a cylinder slips over the can and serves as a shield to hold the chicks away from the hot can.

Ventilation is obtained in two ways. The heating units promote circulation by heating the air in the heater can. This heated air rises and passes out into the hover and thence through and under the curtain to the outside. Cool, fresh air then passes into the heater can through the 2-inch air duct. When the thermostatic regulator has broken the electric circuit, however, the heating units quickly cool and cease to stimulate circulation by heating the air. The second way in which the hover is ventilated is by natural diffusive circulation in and out of the hover through and under the slit curtain. The higher the curtain is above the floor the greater this circulation will be. Also the cooler the weather the greater this circulation will be due to there being more of a difference in temperature between the air of the hover and the air of the room.

The curtain is made of table oilcloth with 2-in. slits 3 in. apart and should hang ½ to 1 in. above the floor. This will provide plenty of ventilation under the hover the first week or ten days. After that time, as mentioned previously, the hover should be raised one inch higher about every week until the curtain is 4 in. above the floor. This can be done by placing one inch blocks under the legs. How frequently and how much at a time the hover should be raised as the chicks grow will depend upon how dry the litter under the hover remains from day to day. It should be dry at all times under normal conditions of feeding, but good ventilation is necessary to keep it so. Therefore, the condition of the litter under the hover each morning is one very good indication of satisfactory ventilation. Another test is to put on a pair of eye glasses and put one's head under the edge of the hover at night to see if the glasses become fogged.

Factors Influencing Soil Moisture Regulation *

II. Soil Moisture Losses and Factors in Prevention

By R. W. Trullinger[1]

A CONSIDERATION of the factors influencing the losses of moisture from soils seems to follow logically a consideration of those factors influencing the absorption and retention of moisture. It seems likely that the establishment of a practical balance between these two sets of factors by means of regulation measures might result in maintaining the practical active moisture requirements.

The analytical summary of findings presented in the first article of this series seemed to indicate that certain mechanical and physicochemical properties of soils govern both the absorption and retention of moisture. While the exact nature and extent of the governing action in both cases seem somewhat speculative as yet, enough is known so that it would appear possible to compare the factors concerned with those which influence losses of soil moisture. In this way it may be possible to piece together sufficient of an outline of the subject of soil moisture regulation to indicate some of the outstanding deficiencies in the available knowledge.

FACTORS IN THE LOSS OF SOIL MOISTURE

Soils under normal conditions are known to lose their content of apparently free and potentially free moisture in different ways and under the influence of various factors. It seems best to begin with a consideration of the losses caused primarily by the downward pull of gravity.

Gravitational Losses. Much moisture is undoubtedly lost from soils by simple downward movement. These losses are, however, subject to certain influences in the soils. Alway and McDole (1)[2] at the Nebraska station showed that five loams when placed in capillary connection with a natural subsoil, saturated with water, and allowed to stand protected from evaporation for several months, lost water until the amount retained bore a close relation to the hygroscopic coefficient. This suggests that under these conditions a large part of the available water in a loam soil may be removed by gravity or by a combination of gravity and some perhaps unknown pulling factor in the subsoil. The latter theory is strengthened somewhat by the further finding that when a coarse layer of sand or gravel separated the soil column from the subsoil the downward movement of the water from the soil was much delayed. However, where the column consisted of successive 2-inch layers of loams differing widely in texture, the order of their arrangement exercised no influence on their final water content.

Veihmeyer and Beckett (2) at the California station showed that the differences in the losses of moisture from cultivated and uncultivated sandy soils, dense clay, silt, sandy loam, and clay loam containing gravel are so small that they fall well within the limit of probable error. No significant difference was noted in the distribution of moisture to a depth of 20 inches. These findings suggest that texture, therefore, may not be so large a factor in determining the total amount of loss by downward movement as has perhaps been thought. However, Puchner (3) at a Bavarian agricultural experiment station showed in several trials with soils of varying composition that the drainage water decreased as the clay and humus content increased, and increased with the sand, and the finer the sand the greater was the drainage. This indicates that texture, colloid content, and perhaps specific surface may after all have some influence in determining gravity losses.

Loughridge (4) at the California station showed that the unobstructed movement of water in loam soils when applied to the surface is downward, with great irregularity in the rate of progress and in the amount of water retained at various depths. Willard and Humbert (5) at the New Mexico station showed that the loss of irrigation water by seepage from sandy loam soils was in proportion to the amount of water applied. Israelsen and West (6) at the Utah station verified this result and found further that the quantities of water retained were not appreciably influenced by the depth of the soil selected as the index of capacity. Willard and Humbert also found that the downward loss of irrigation water was more rapid the more sandy and gravelly the soil.

It seems likely, therefore, that factors other than gravity alone influence the loss of moisture from soils by downward movement. In fact McLaughlin (7) of the U. S. Department of Agriculture showed that where capillary movement of moisture downward in soils was assisted by gravity, the type of soil was of importance in limiting the extent of the movement. Porosity was not the only factor, but the so-called transporting power of the soil was of prime importance. The heavy and less porous soils showed a relatively greater percentage of moisture movement the first day or two and a relatively slower rate of movement the last few days of the experiments, than did the light and more porous soils, which showed a more uniform and extended moisture movement.

Measures for the prevention of losses of moisture by downward movement in soils seem somewhat out of the question, beyond those perhaps which will so modify the physicochemical composition of the soil as to retard such downward movement. The problem involved seems to be more one of determining the amount of such loss for different soils and conditions and properly compensating for it in moisture regulation measures for different cropping practices.

Evaporation Losses. Losses of moisture from soils by evaporation seem likely to be of importance, depending upon climatic and other conditions. Apparently under certain conditions they are not of great importance. Veihmeyer and Beckett (2), for example, found that under California conditions the loss of moisture by evaporation for three summer months directly from the surface of a clay loam soil was very small and was not affected by cultivation. Moisture losses by evaporation from cultivated and uncultivated soils were confined almost entirely to the surface foot. Apparently under those conditions evaporation losses from the surface of soils are negligible when compared to the amount of water required to support a crop.

The Rothamsted Experimental Station (8) found that little water rises to the surface from the subsoil when the ground water falls to four or more feet below the surface. A definite relation was found, in fact, between the potential evaporating power at the surface and the change in ground water level.

Bouyoucos (9) at the Michigan station concluded further that the amount of water lost from soil by water vapor is very small, and there is no rising of vapor during the night from the warmer soil below to the cold soil above. Barker (10) at the Nebraska station found that the loss of water due to direct evaporation from the surface of the soil is a very small factor after the water becomes thoroughly distributed in the soil.

Leather (11) of the Department of Agriculture of India showed that during a dry period water moves upward toward the surface of a soil from a limited depth only, and is lost

*Second article of a series by Mr. Trullinger under the general title "Factors Influencing Soil Moisture Regulation." These articles are intended to lay a foundation for a program of research in the regulation of soil moisture. Since there has been considerable agitation of this subject in connection with drainage and irrigation practices and also in connection with the development of cultivating and tillage machinery, it would seem that the material presented in these articles is particularly timely. It seems likely that a more accurate knowledge of the manner of existence and functions of water in soils and of the ways in which this water may be regulated should provide a definite basis for the development of drainage and irrigation practices and structures and of tillage and cultivation methods and machinery to meet the requirements of certain soils growing certain crops.

[1]Specialist in agricultural engineering, Office of Experiment Stations, U. S. Department of Agriculture. Mem. A.S.A.E.

[2]Numbers in parenthesis refer to the list of references that follows this article.

from the soil by evaporation at a rate dependent upon the amount present. Buckingham and Cameron (12) of the U. S. Department of Agriculture found that the loss of moisture from soils by evaporation from points below the surface is quite small in comparison with that taking place at or very near the surface. The movement of water vapor through the soil is quite slow, and was found to follow the law governing the diffusion of other gases through porous media. Mohr (13) of the Department of Agriculture of the Dutch East Indies found that evaporation was uniformly higher from a water surface than from the surface of either a wet or only a moist soil.

These results would suggest that evaporation losses from a soil depend to a considerable extent upon the presence of water at the soil surface, and seem to indicate that vapor movements from any great depths, resulting in evaporation losses, are not very likely to occur.

Harris and Robinson (14) at the Utah station found, however, that the evaporation of moisture from loam, sand, clay, and muck soils increases with the initial quantity in the soil. The increase is not so great with the higher percentages as with the lower, and there seem to be a number of critical points at which the rate of loss changes rapidly. The rate of evaporation from a moist soil decreases very rapidly as the humidity of the air increases. Air currents were found to increase greatly the loss up to a certain wind velocity beyond which the increase is slight. The evaporation was higher from the finer soil particles than from the coarser when both were completely saturated. Reducing the intensity of the sunshine reduced the rate of evaporation, and it was markedly affected by slight changes in temperature.

Alway (15) at the Nebraska station showed that under Nebraska conditions a soil containing an amount of moisture corresponding to its hygroscopic coefficient loses water very rapidly when exposed to an ordinarily dry atmosphere. Willard and Humbert (5) at the New Mexico station also found that the evaporation loss from soils is greater the higher the temperature and the lower the humidity, but showed, in addition, that the amount lost is proportional to the surface exposed. An effect of both climate and soil properties on evaporation losses of moisture from soils thus seems likely.

Russel and Weakley (16) at the Nebraska station found that the evaporation of water from a free water surface into the atmosphere or through either dry soil or sand is a linear function of the saturation deficit. The rate of evaporation varies with the porosity of the material but is not affected by its hygroscopicity. As much water was found to pass from a free water surface through dry, coarse sand as through dry, coarse, granular soil of identical permeability coefficient. The size rather than the quantity of pore space determined the extent of the water lost. The evaporation of water from a wet mass of soil, when not more moist than the field-carrying capacity, seemed to follow all of the laws of vapor movement. As much water was lost from wet soil columns when they were broken by air gaps as when they were continuous.

Thomas (17) at the Utah station found that the vapor pressure-moisture curves of sand, silty clay loam, clay loam, and a silty clay separate are rectangular hyperbolas over a wide range of moisture contents, indicating that the vapor pressure is proportional to the reciprocal of the moisture content.

These results suggest that evaporation is primarily dependent upon the free and active water in soils and the physical factors governing its existence as such. They seem further to indicate that, under certain conditions at least, measures taken to break the continuity of the soil mass are perhaps not so effective in checking evaporation losses as might be expected.

Fisher (18) at the Rothamsted Experimental Station showed that the moisture contents of soils at which the rates of evaporation begin to decrease, that is, at which the vapor pressure of the retained moisture begins to decrease are characteristic for each soil. They represent some function of the total surface of the soil grains, which in turn depends upon the average size of the grains. Keen (19) at the same station found that the rate at which soils lost water by evaporation at a constant temperature depended upon the amount of clay and organic matter present. The differences due to organic matter were more obvious in soils containing the larger amounts of clay and were small in sandy soils. Evidence was secured that the moisture equivalent of these soils measures the percentage of water at which evaporation is first directly affected by the soil particles, and that at percentages of water in excess of the moisture equivalent, evaporation takes place substantially from a free water surface. These results seem not only to substantiate some of the deductions made above but also tend to classify the forms of soil moisture with reference to the order of the evaporation process and some of the factors governing it.

Westerman (20) and de Angelis d'Ossat (21) from Danish and Italian agricultural experiment stations, respectively, showed that evaporation of moisture was always greater from clay than from sandy soils, and von Seelhorst (22) at the University of Gottingen found it to be always greater from loam than from sandy soil. Pohlman (23) at another German experiment station showed that evaporation from soil depends not only on grain size but much more on the moisture capacity of a soil. Since this in turn tends to increase with the fineness of material and is influenced by the arrangement and condition of the grains, the subsequent finding was naturally that evaporation increased with the absorptive power of a soil for water. This is strengthened by the finding of Blanck (24) at the University of Gottingen that evaporation was most rapid from unlimed soil and was least from soils treated with caustic lime. It was furthermore found by Pohlman that only the hygroscopic water remained in thin layers of soil after evaporation under normal conditions had ceased.

These results on losses of moisture from soils seem rather significant when considered in connection with soil moisture regulation measures which are developed, particularly from the standpoint of moisture conservation. They seem to suggest that there is considerably more involved in the development of measures for the conservation of soil moisture than arbitrarily selected cultivation or mulching practices. It appears desirable, therefore, to consider some of the principles underlying these practices at this point, in spite of the fact that the order of discussion is perhaps not fully logical.

FACTORS IN PREVENTING MOISTURE LOSSES BY EVAPORATION

Mulching and cultivation practices for the prevention of losses of soil moisture by evaporation are quite common. It would appear, however, that their use for this purpose should be based upon more than the results of practical experience and tradition, since they are power and labor-consuming practices and are therefore essentially expensive.

Mulching Practices. The value of mulching in soil moisture retention appears to depend largely on the prevailing conditions under which it is practiced. Beckett and Veihmeyer (25) at the California station showed in field experiments that soil mulches have a very limited effect in reducing the loss of water by evaporation from the surface when the initial amount of water present is not above the normal water-holding capacity. Shaw (26) at the same station showed that soil moisture representing the normal capacity is essentially static. In this condition mulches have little or no effect in conserving soil moisture, as upward movement to supply water for evaporation does not occur.

McCall (27) at the Washington station found that the soil mulch has an inhibitory effect on moisture absorption under conditions where individual rains are not of sufficient volume to penetrate the mulch fully. However, the mulch prevents the loss of moisture already in the soil by checking evaporation. The practical use of the soil mulch in moisture conservation is therefore considered to depend on climatic conditions which influence the prominence of either the inhibitory effect on absorption or the positive effect on retention, or both. Grantham and McCool (28) at the Michigan station found that the differences between the amounts of water lost from unmulched soils and from soils mulched with 3 inches of soil were negligible. It was concluded that the importance of the soil mulch in soil moisture conservation has been somewhat

overemphasized. Young (29) at the Nebraska station found that a loose soil mulch was not much more effective than an unmulched soil in retarding the evaporation of moisture that is well established in the soil. It was also found that if a hard layer of soil dries out to a depth of 2 or 3 inches it will act as a mulch.

It is interesting to note the apparent effect of climate in this connection, however. Harris and Yao (30) found at the Utah station that an effective mulch of one inch of straw is capable of preserving 60 per cent more moisture in the soil than is retained without mulching. Straw was the most efficient mulch material used, followed in order by hay, grass, wood shavings, and manure. The loss of moisture from the soil was correlated with the percentage of moisture retained by the mulch, which corresponds somewhat with the findings of the Washington station noted above. This suggests that the principles involved in mulching are the same regardless of conditions. Harris and Yao further found that the effectiveness of mulching increased with its depth. The rate of evaporation from soils under mulch varied according to their moisture contents, the finer soils losing the most water. However, clay ground into a fine powder lost less water than loam, suggesting the influence of colloidal phenomena.

Harris and Turpin (31) found further than, under Utah conditions, the effect of mulches in preventing moisture losses under both irrigation and dry farming conditions was noticeable several feet below the surface, but the surface foot showed the greatest benefit. This influence was noted to greater depths under irrigated than under dry land farming conditions. A straw mulch was considerably better than a 2-inch soil mulch. However, the latter was more effective than no mulch with the weeds pulled. Burr (32) at the Nebraska station also found that artificial mulches of straw or hay were more effective than soil mulches and a 3-inch mulch was more effective than a shallower one.

Fortier and Beckett (33) of the U. S. Department of Agriculture found that a dry granular soil mulch 3 inches deep reduced evaporation losses from soil at least one-half. A mulch 6 inches deep reduced them 75 per cent and a 9-inch mulch was still more effective but was too expensive to be profitable. This seems to bear out the contention that the effectiveness of mulches increases with their depth, but indicates that there are quite definite practical limitations for the use of this conservation measure which must be determined for each set of conditions.

Harris and Jones (34) found further that mulched fallow retained only slightly more moisture than unmulched fallow from which the weeds were removed with a sharp hoe. It was concluded that destroying weeds is more important in this connection than maintaining a mulch. Deep mulching was more effective in retaining moisture in spring plowed fallow than in fall plowed fallow. Manure, especially when added at rates as high as 20 tons per acre, increased the water-retaining power of cropped soil and slightly increased that of the second foot of fallow. Thin mulches, if kept dry, reduced evaporation. Dry mulches composed of fine particles seemed to be less effective than when composed of coarser particles and compacting the surface of the soil increased evaporation.

Kruger (35) at a German agricultural experiment station found that in dry weather the evaporation from plain moor soil was greater than from soil covered with fine sand. The evaporation from moor soil covered with coarse sand was less yet. However, these conditions were reversed during the first days following a rain. As soon as the surface of the coarse sand became dry the original conditions as regards evaporation again prevailed, although evaporation continued for some time from the soil covered with fine sand. These conditions prevailed, especially where the rainfall was heavy enough to wet the sand covering through completely. These findings seem to bear out some of those of the Washington and Utah stations noted above, and suggest that texture and structure of the mulch are factors in its effectiveness as well as its depth.

Bouyoucos (9) of the Michigan station also established the fact that when a moist column of soil was in contact with a dry column of soil, and the former was kept at 20 and 40 degrees C. and the latter at 0 degrees C. for 8 hours, the amount of moisture moved from the moist and warm soil to the dry and cold soil increased with the temperature and the moisture content. When the temperatures of the two soil columns were reversed, there was little if any movemnt of water. The conclusion was therefore drawn that temperature has a very marked influence on the conservation of moisture by mulches.

These results seem to indicate that a knowledge and consideration of both environmental conditions and soil physics are necessary in the rational development of mulching practices for soil moisture control. Climate seems to be a factor in their effectiveness, especially temperature, but even the influence of climate is apparently dependent to a considerable extent upon the texture, structure, depth, and moisture content of the mulch itself, and probably on its physicochemical properties. This suggests that there is yet considerable to be learned about mulching. In fact, Shaw (36) at the California station and Stewart (37) at the experiment station of the Hawaiian Sugar Planters' Association observed that soil moisture losses were appreciably reduced by a covering of asphalt coated paper, although this was not sufficient in the former case to affect the growth of crops favorably. However, the fact that the reduction in moisture loss was accompanied by higher and more uniform temperatures in both cases and a more rapid elaboration of soil nutrients in one case at least is significant, and suggests that certain principles of soil physics and physicochemistry, and perhaps of thermodynamics, must yet be elaborated before the mulching process is fully developed.

Cultivation Practices. Cultivation practices other than those involving surface mulching are known to result in physical, chemical, and bacteriological changes in soils, any of which may influence the ability of the soil to retain water against the force of gravity or the process of evaporation. Rather extensive studies have been made of cultivation under various conditions, but there seems to be inadequate explanations for many of the phenomena observed which will permit more definite use of the principles involved.

Quite a difference of opinion apparently exists relating to the value of cultivation in connection with the conservation of moisture in soils. The California station (38) found, for instance, that under some conditions in the state, cultivation is of negligible value in conserving soil moisture except as such cultivation eliminates weed growth. The same result was reported by Call and Sewell (39) from studies at the Kansas station. On the other hand, Fraps (40) at the Texas station found that both cultivation and manuring increased the quantity of water held at the ends of wet periods by clay, black clay, loam, sand, clay loam, and black clay loam soils. They also increased the water content of these soils at the ends of dry periods and decreased the loss by evaporation. This was true even though there was a variation of about 50 per cent in the capacities of the various soils to hold water during wet periods and to retain it during dry periods. Fortier and Beckett (33) found that the effect of cultivation in lessening evaporation was especially marked in the compacting ing evaporation was especially marked in the heavier soils.

Thomas (41) of the California station showed that trees, in soil which was harrowed to a depth of from 3 to 5 inches before it was properly dried, followed by two or three similar cultivations preceding the next irrigation, suffered from lack of moisture. This suggests that the initial moisture content of the soil may influence the value of cultivation in conserving moisture.

McCall and Holtz (42) of the Washington station found that with a light intermittent rainfall, followed by drying winds, a comparatively firm soil condition favored absorption the most, while a loose soil condition hindered the process. At a moisture content near the field capillary capacity for a given soil type, the soil tended to settle or naturally refirm itself to the greatest degree after stirring. Under such conditions deeper tillage was possible without an equally detrimental effect on absorption. At a lower moisture content the soil tended to remain in a looser condition after being stirred. It was concluded that the lower the average rainfall is, the more shallow should be the average depth of plowing, and that in general the depth of plowing should decrease with the advance of the spring season.

Harris and Yao (30) at the Utah station also found that under dry farming conditions shallow cultivation is preferable to deep cultivation for moisture conservation. The same result was established by Cardon (43) at the Utah station and by Burns (44) of the Agricultural Society of Cairo, especially during the hot summer months. Harris and Turpin (31) at the Utah station showed that subsoiling 15 inches deep had little influence on moisture, while spring disking was of rather distinct benefit. Spring plowing under dry farming conditions conserved moisture better than fall plowing, especially below the first foot. Where no irrigation water was applied the soil retained as much moisture when the weeds were pulled as when the soil was cultivated. Burr (32) at the Nebraska station found that summer tillage is the most effective means of storing water in fairly uniform fine sandy loam soil, the annual storage by this means varying from 10 to 33 per cent of the seasonal rainfall. Plowing was found to be better than disking for accumulating water in this soil. Harris and Jones (34) at the Utah station found that disking stubble before fall plowing in deep alluvial, reddish brown, clayey to sandy loam soils or after harvest before spring plowing, was not beneficial in moisture storage.

Mendes de Godoy (45) of the Brazilian Agricultural College found that there was a lower water content in the first 6 inches of seven different soils after one cultivation than in uncultivated soil. After four succeeding cultivations, however, there was always a difference in favor of the cultivated soil. Soils containing the greatest percentages of coarse materials retained the most water, although they showed the greater rate of infiltration. This apparently unusual result was due partially to the manner of distribution of the different sizes of particles in the soil. Fortier and Beckett (33) noted a tendency of the uncultivated surfaces of light sandy soils to mulch themselves.

These results seem to indicate that shallow cultivation is likely to be a greater factor in soil moisture conservation than deep cultivation, especially under arid conditions. Apparently, so far as is known, weed eradication seems to be at least as great a factor in moisture conservation as cultivation under a number of conditions. It seems quite evident, however, that some other factor or factors are involved in the effectiveness of cultivation. Time of year seems to have some influence as well as nature, number, and sequence of cultivations. This suggests that the influence of cultivation on some of the physical or physicochemical properties of soils that in turn influence their moisture-retaining powers may be of considerable importance. Apparently tilth texture is not so important a factor as tilth structure. It seems only natural, therefore, to suggest that an elucidation of those conditions of tilth structure which favor moisture retention under any conditions, and of the factors governing their production by tillage machinery, is necessary before cultivation as a moisture conservation measure can be placed on a rational basis.

CONCLUSION

The fact that investigations of losses of soil moisture have been made quite generally would seem to indicate the importance of the subject. While it is evidently more important in the arid and semiarid regions than in the humid regions, the occasional occurrence of drouth conditions in humid regions lends considerable significance to soil moisture losses and the factors affecting them.

The results discussed above appear to indicate that practically the same internal and external factors which influence the manner of occurrence, absorption, and retention of moisture in soils also have some bearing on the nature and extent of the losses of moisture from soils by gravity and evaporation. This seems rather strikingly indicated when the results of investigations of mulching and cultivation practices are considered.

It seems likely that a more intimate knowledge of the details of the phenomena involved for definite specific conditions will be necessary before compensation for gravity losses can be made intelligently as well as adequately and before evaporation losses can be controlled profitably as well as effectively.

List of References

1. Alway, F. J., and McDole, G. R. Relation of the water-retaining capacity of a soil to its hygroscopic coefficient. (U. S. Dept. Agr., Jour. Agr. Research, 9 (1917), No. 2, pp. 27-71) (E. S. R., 37, p. 117).
2. Veihmeyer, F. J., and Beckett, S. H. (California Sta. Rpt. 1922, pp. 104-107) (E. S. R., 48, p. 585).
3. Puchner, H. Investigations on the water-carrying power of soil. (Internatl. Mitt. Bodenk., 1 (1911), No. 2, pp. 99-137) (E. S. R., 26, p. 218).
4. Loughridge, R. H. Distribution of water in the soil in furrow irrigation. (U. S. Dept. Agr., Office Expt. Stas. Bul. 203) (E. S. R., 20, p. 815).
5. Willard, R. E., and Humbert, E. P. Soil Moisture. (New Mexico Sta. Bul. 86) (E. S. R., 29, p. 620).
6. Israelsen, O. W., and West, F. L. Experiments on capacities of soils for irrigation water. (Utah Acad. Sci. Trans. 2 (1918-1921), pp. 139-141). (E. S. R., 48, p. 88).
7. McLaughlin, W. W. Capillary movement of soil moisture. (U. S. Dept. Agr. Bul. 835) (E. S. R., 43, p. 722).
8. Soil tilth and cultivation. (Rothamsted Expt. Sta., Harpenden, Rpt. 1923-24, pp. 28-30) (E. S. R., 54, p. 623).
9. Bouyoucos, G. J. Effect of temperature on movement of water vapor and capillary moisture in soils. (U. S. Dept. Jour. Agr. Research, 5 (1915), No. 4, pp. 141-172) (E. S. R., 34, p. 215).
10. Barker, P. B. The moisture content of field soils under different treatment. (Nebraska Sta. Rpt. 1911, pp. 106-110) (E. S. R., 28, p. 218).
11. Leather, J. W. The loss of water from soil during dry weather. (Mem. Dept. Agr., India, Chem. Ser., 1 (1908), No. 6, pp. 75-116) (E. S. R., 20, p. 214).
12. Buckingham, E., and Cameron, F. K. Studies on the movement of soil moisture. (U. S. Dept. Agr., Bur. Soils Bul. 38) (E. S. R., 18, p. 820).
13. Mohr, E. C. J. Evaporation from water and soil surfaces. (Bul. Dept. Agr. Indes Neerland., 1909, No. 29) (E. S. R., 22, p. 617).
14. Harris, F. S., and Robinson, J. S. Factors affecting the evaporation of moisture from the soil. (U. S. Dept. Agr., Jour. Agr. Research, 7 (1916), No. 10, pp. 439-461) (E. S. R., 36, p. 421).
15. Alway, F. J., Kline, M. A., and McDole, G. R. Some notes on the direct determination of the hygroscopic coefficient. (U. S. Dept. Agr., Jour. Agr., Research, 11 (1917), No. 4, pp. 147-166) (E. S. R., 38, p. 210).
16. Russell, J. C., and Weakley, H. E. (Jour. Amer. Soc. Agron. 17 (1925) No. 10, pp. 642, [643].
17. Thomas, M. D. Aqueous vapor pressure of soils. (Soil Sci., 11 (1921), No. 6, pp. 409-434) (E. S. R., 46, p. 18).
18. Fisher, E. A. Some factors affecting the evaporation of water from soil. (Jour. Agr. Sci. [England], 13 (1923), No. 2, pp. 121-143) (E. S. R., 50, p. 812).
19. Keen, B. A. The evaporation of water from soil.—II, Influence of soil type and manurial treatment. (Jour. Agr. Sci. [England], 11 (1921), No. 4, pp. 432-440) (E. S. R., 50, p. 812).
20. Westerman, T. Researches on evaporation from bare and cultivated soils. (K. Vet. og Landbohjsk [Copenhagen], Aarsskr. 1922, pp. 1-55) (E. S. R., 50, p. 117).
21. De Angelis d'Ossat, G. Experiments on evaporation from soils. Staz. Sper. Agr. Ital., 51 (1918), No. 1-2, pp. 41-55) (E. S. R., 42, p. 513).
22. Von Seelhorst. Contributions from the agricultural experiment station of the University of Gottingen. (Jour. Landw., 54 (1906), No. 4, pp. 313-342) (E. S. R., 18, p. 881).
23. Pohlmann, A. Evaporation from soil. (Internatl. Mitt. Bodenk., 12 (1922), No. 1-2, pp. 36-53) (E. S. R., 48, p. 513).
24. Blanck, E. The influence of lime on the movement of water in soils. (Landw. Jahrb., 38 (1909), No. 5-6, pp. 715-758) E. S. R., 22, p. 219).
25. Beckett, S. H., and Veihmeyer, F. J. (California Sta. Rpt. 1921, pp. 19, 20, 21, 22, 23) (E. S. R., 47, p. 617).
26. Shaw, C. F. The normal moisture capacity of soils. (Soil Sci., 23 (1927), No. 4, pp. 303-317).
27. McCall, M. A. The soil mulch in the absorption and retention of moisture. (Jour. Agr. Research [U.S.], 30 (1925), No. 9, pp. 819-831) (E. S. R., 53, p. 719).
28. Grantham, G. M., and McCool, M. M. Experiments on soil moisture. (Michigan Sta. Quart. Bul., 2 (1920), No. 3, pp. 142-144) (E. S. R., 42, p. 621).
29. Young, H. J. Soil mulch. (Nebraska Sta. Rpt. 1911, pp. 124-128) (E. S. R., 28, p. 218).
30. Harris, F. S., and Yao, H. H. Effectiveness of mulches in preserving soil moisture. (Jour. Agr. Research [U.S.], 23 (1923), No. 9, pp. 727-742) (E. S. R., 49, p. 317).
31. Harris, F. S., and Turpin, H. W. Movement and distribution of moisture in the soil. (U. S. Dept. Agr., Jour. Agr. Research, 10 (1917), No. 3, pp. 113-155) (E. S. R., 37, p. 623).
32. Burr, W. W. The storage and use of soil moisture. (Nebraska Sta. Research Bul. 5 (1914)) (E. S. R., 31, p. 419).
33. Fortier, S., and Beckett, S. H. Evaporation from irrigated soils. (U. S. Dept. Agr., Office Expt. Stas. Bul. 248) (E. S. R., 27, p. 121).
34. Harris, F. S., and Jones, J. W. Soil moisture studies under dry farming. (Utah Sta. Bul. 158 (1917)) (E. S. R., 38, p. 319).
35. Kruger, E. Evaporation from moor soils and moor soils covered with sand. (Internatl. Mitt. Bodenk., 12 (1922), No. 1-2, pp. 4-10) (E. S. R., 48, p. 513).

(Continued on page 193)

Research in Agricultural Engineering

A department conducted by the Research Committee of the American Society of Agricultural Engineers

Kinematics and Dynamics of the Wheel-Type Farm Tractor*

VII. Conclusions and Lecture Demonstration Apparatus

By E. G. McKibben[1]

THE conclusions listed below are given in the order in which the principles on which they are based were developed in the preceding articles of this series and not in the order of their relative importance.

CONCLUSIONS (See Fig 37)

1. Except when turning to the right or left the motion of a tractor consists of linear motion parallel to the motion (m) of the center of the rear axle, rotation about the rear axle, or a combination of these motions.

2. The above motions may be considered as rotation about an instantaneous axis which is parallel to the rear axle, and which lies somewhere in the plane (represented by QO extended) which contains the center of the rear axle and which is perpendicular to the motion (m) of the center of the rear axle.

3. The center of gravity of a given tractor may be rather easily located with sufficient accuracy, by the use of simple apparatus, by determining the weight supported by the front and rear wheels for different angles of the wheelbase with the horizontal.

4. The important external forces which may act upon a tractor are its weight (W), soil reactions, load resistance (P_o), inertia, and, under certain conditions, wind resistance (F_1).

5. The soil reactions may be divided into tractive (R_1), downward (R_2), supporting (R_3 and R_5), and resisting (R_4 and R_6) components.

6. The inertia effects due to both angular and linear acceleration may be most simply represented by two inertia forces $\frac{Wa_h}{g}$ and $\frac{Wa_v}{g}$ acting through the center of gravity and two inertia couples ($I_t \propto_t$ and $I_w \propto_w$).

7. The force of inertia $\frac{Wa_h}{g}$ due to the sudden starting of a tractor may under certain conditions be very large and thus bear an important relation to the stability of the tractor.

8. Thus under certain conditions the sudden engagement of the clutch not only throws a great strain upon the transmission parts, but may also dangerously disturb the stability of the tractor.

9. Except under very unusual conditions the moment due to the gyroscopic action of the flywheel does not have an important effect upon the stability of the tractor.

10. In setting up the moment equation of the external forces acting upon a tractor, any axis parallel to the rear axle may be assumed as the axis of rotation, but the line through the intersection (C) of the resultant (R_3) of the supporting soil reactions against the rear wheels and the resultant (R_1) of the tractive soil reactions against the drivewheels is the most convenient and results in the simplest equation.

11. The overturning moment in pounds-feet due to the load resistance is equal to the load resistance (P_o) in pounds times the perpendicular distance (x_o) in feet from the intersection (C) of the resultant (R_3) of the supporting soil reactions against the rear wheels and the resultant (R_1) of the tractive soil reactions against the drivewheels, to the line of action of the load resistance.

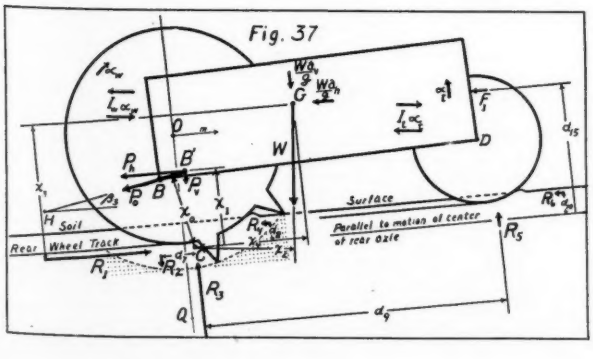
12. The moment $P_h x_1$ is equal to and may be substituted for the moment $P_o x_o$.

13. The exact location of the intersection (C) of the resultants of the supporting and tractive soil reactions is affected by the tractor, soil, load, and speed; is constantly

*Last of a series of seven articles. The first installment appeared in the January issue of AGRICULTURAL ENGINEERING. The material presented in these articles was obtained as the result of an agricultural engineering project of the agricultural experiment station, University of California. It has been edited and approved by the Research Committee of the American Society of Agricultural Engineers.

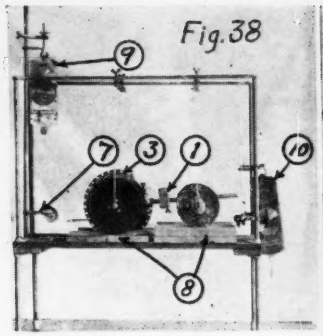
[1]Junior agricultural engineer, University of California. Mem. A.S.A.E.

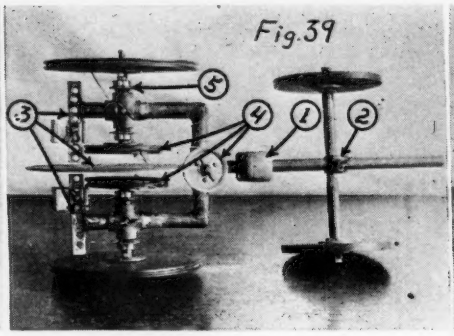
Fig. 37



Notation of Fig. 37

B, point of hitching to rigid frame of tractor
B', point of intersection of line HB extended with plane through C perpendicular to m
C, point of intersection of R_1 and R_2
F_1, wind resistance
G, center of gravity
H, point of hitching to rigid frame of implement
I_t, moment of inertia of entire tractor about an axis through G parallel to the rear axle
I_w, moment of inertia of drivewheels about the center of the rear axle
O, center line of rear axle
P_o, load resistance
P_h, component of P_o parallel to m
P_v, component of P_o perpendicular to m
QO, line through O perpendicular to m
R_1, resultant of tractive soil reactions against drivewheels
R_2, resultant of downward soil reactions against drivewheels
R_3, resultant of supporting soil reactions against drivewheels
R_4, resultant of resisting soil reactions against drivewheels
R_5, resultant of supporting soil reactions against front wheels
R_6, resultant of resisting soil reactions against front wheels
W, weight of entire tractor
a_h, acceleration of point G parallel to m
a_v, acceleration of point G perpendicular to m
$\propto_t$, angular acceleration of entire tractor with respect to the earth
$\propto_w$, angular acceleration of drivewheels with respect to the frame of the tractor
β_3, angle between line of action of P_o and line parallel to m
d_7, distance from C to line of action of R_2
d_8, distance from C to line of action of R_4
d_9, distance from C to line of action of R_5
d_{10}, distance from C to line of action of R_6
d_{15}, distance from C to line of action of F_1
g, acceleration of gravity (32.2 ft. per sec.)
m, direction of motion of the center of the rear axle
x_o, distance from C to line of action of P_o
x_1, distance from C to B'
x_2, distance from C to line of action of W
x_3, distance from C to line of action of $\frac{Wa_h}{g}$
x_4, distance from C to line of action of $\frac{Wa_v}{g}$





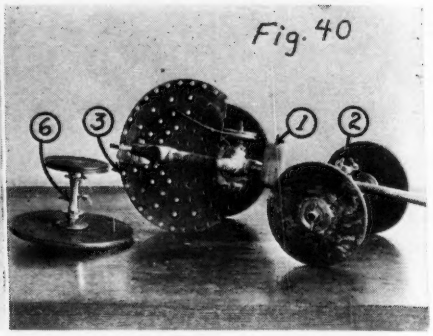


Fig. 38. Apparatus for demonstrating the kinematics and dynamics which determine the behavior of a wheel-type tractor. Fig. 39. Top view of apparatus shown in Fig. 38. Fig. 40. Drivewheel and rear axle assembly removed showing the adjustable drawbar

changing within certain limits; and for many soil conditions is one of the unknown facts of soil traction dynamics. Under normal working conditions, C will probably be located about as indicated in Fig. 37. It would be easily possible for C to be located anywhere between the soil surface and the lug point circumference. Under certain nonuniform soil conditions it would be possible for C to be located anywhere in the shaded area.

14. The load resistance moment arm (x_o) or (x_1) should be as short as possible and still maintain the required drawbar clearance.

15. From the standpoint of stability it would be ideal if the lines of action of the load resistance (P_o) and the resultant (R_1) of the tractive soil reactions against the drivewheels could coincide and pass through the center of gravity (G).

16. Changing the height of the point of hitch (H) to the implement, the length of the hitch (HB), and the location, with respect to the rear axle (O), of the point of hitch (B) to the tractor all affect the rate of change of the moment arm of the load resistance as the tractor rises in front, and in many cases affects the actual length of the load resistance moment arm before the tractor starts to rise in front, and thus all affect the potential stability of the tractor.

17. Under usual operating conditions raising the point of hitch (H) to the implement, shortening the hitch (HB), lowering the point of hitch (B) to the tractor, or moving the point of hitch (B) to the tractor to the rear increases the potential stability of the tractor.

18. Considering only conditions of uniform motion, if the tractor is to be operated only on level ground the center of gravity (G) should be as low as possible with respect to the rear axle (O) and still maintain the required clearance between the frame and soil.

19. If the tractor is to be operated on grades the center of gravity (G) should be as low as possible with respect to the soil surface and still maintain the desired clearance between the tractor frame and the soil.

20. The greatest clearance for a given position of the center of gravity, or lowest position of the center of gravity for a given clearance, is obtained with the material of the tractor, outside of the wheels, spread evenly over the entire width and length of the tractor with the least possible vertical thickness.

21. The distance of the center of gravity (G) in front of the rear axle (O) should be such as to leave just sufficient effective weight at the front wheels to enable satisfactory steering, when the tractor is operating with the most probable hitch height and developing its rated drawbar pull in low gear.

22. The relationship between the location of the center of gravity (G), point of hitch (H) to implement, and point of hitch (B) to tractor should be such that when operating on the steepest practical grade the ratio $\frac{x_2}{x_1}$ will increase when the tractor rises in front, thus tending to maintain the stability of the tractor.

23. Drivewheels should have as small a moment of inertia (I_w) as possible and still maintain the required strength, durability and dimensions.

Notation of Figs. 38 to 40

1. Movable weight for shifting the location of the center of gravity
2. Provision for adjusting the length of the wheelbase
3. Drawbar permitting of a wide variation in the location of the true point of hitch to the tractor, even permitting its location to be below the line of action of the tractive soil reaction
4. Differential
5. Rear-axle bearing (bicycle front wheel hub)
6. Drivewheel, rear axle, rear-axle bearing, and differential-pulley assembly
7. Provision for adjusting location of true point of hitch to implement
8. Provision for showing the effect of digging in, crossing a ridge, or striking a large stone or root with the drivewheels
9. Scale for measuring drawbar pull
10. Scale for measuring the tractive and supporting soil reactions

24. So far as possible, without interfering with other requirements, the parts of a tractor should be arranged to give the maximum moment of inertia about the rear axle.

25. The stability of a tractor, the drivewheels of which have started to dig in, may be dangerously disturbed by placing a timber or other object giving positive traction under the points of the lugs. The danger is increased, if the tractor is on an up-grade, if the length of the lugs (effective drivewheel radius) is increased, and in many cases if the drawbar load has been disconnected. Under these conditions the clutch should be engaged carefully and slowly, and if the situation is very critical the tractor should be backed out.

26. If there is any probability of the stability of the tractor being destroyed, it should be protected by projecting some part of the frame to the rear of the drivewheels.

27. From the standpoint of maximum stability and tractive ability the wheelbase should be as long as possible and still permit a satisfactory turning radius and ability to cross checks or ridges.

28. A crossgrade, sidedraft, or an offset drawbar, or combinations of these conditions may result in unequal supporting soil reactions against the drivewheels, which, if the tractor has a differential axle, will decrease its tractive ability.

29. Increasing the width of a tractor decreases the effect mention in [28] of a crossgrade, sidedraft or offset drawbar.

30. Lowering the center of gravity decreases the effect mentioned in [28] of a crossgrade.

31. Lowering the line of action of the load resistance decreases the effect mentioned in [28] of sidedraft.

32. Unless the implement being used is designed for the given tractor and soil conditions, the positions of hitch points (H and B) to both implement and tractor, and the length of the hitch (HB) should be adjustable.

33. The effect upon the location of the center of gravity and upon location and direction of action of the load resistance (P_o) should be carefully considered before designing an implement to be rigidly attached to a tractor frame.

34. The maximum possible sustained drawbar pull of any given tractor may be limited by its drivewheel torque, stability or tractive ability.

35. The gear ratio, engine torque and hitch adjustment of a tractor should be such that, when operating under average conditions, tractive ability will be the factor which limits the maximum possible drawbar pull.

36. Where the torque of the tractor limits the drawbar pull an upgrade decreases and a downgrade increases the maximum component (P_h), parallel to the motion of the center of the rear axle, of the load resistance, which the tractor can overcome, by the sine of the angle of the grade times the weight of the tractor.

37. Unless the stability of the tractor is destroyed, increasing the length of the load resistance moment arm (x_0 or x_1) increases the tractive ability of a given rear-drive tractor and decreases the tractive ability of a given front-drive tractor.

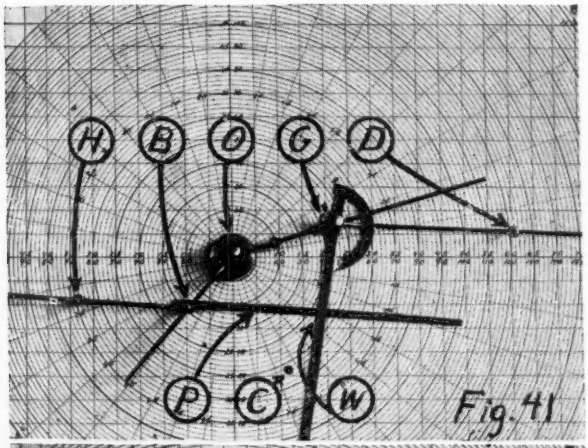
38. Increasing the angle (β_4) which the line of action of the load resistance makes with the direction of motion of the center of the rear axle, while x_1 is held constant, increases the tractive ability of a rear-drive tractor but has no effect upon the tractive ability of a front-drive tractor.

39. Sudden stopping of a tractor by increased load resistance will not endanger its stability above the maximum load resistance due to tractive ability unless the distance x_1 is greater than distance x_3.

40. If it is possible for the load resistance to be greatly increased very suddenly the tractor, hitch, and implement parts are subjected to very great stresses and should be protected by a drawbar spring or some type of overload release.

41. By the use of a proper drawbar spring it is possible to limit definitely the increase (above tractive ability) in the drawbar pull due to a sudden stopping of a tractor by an increased load resistance.

42. The increase (above its tractive ability) in the drawbar pull parallel to the direction of motion of the center of the rear axle of the tractor, caused by the sudden stopping of the implement is proportional to the weight of the tractor, the square of the speed of the tractor; and inversely proportional to the distance in which the tractor is stopped.



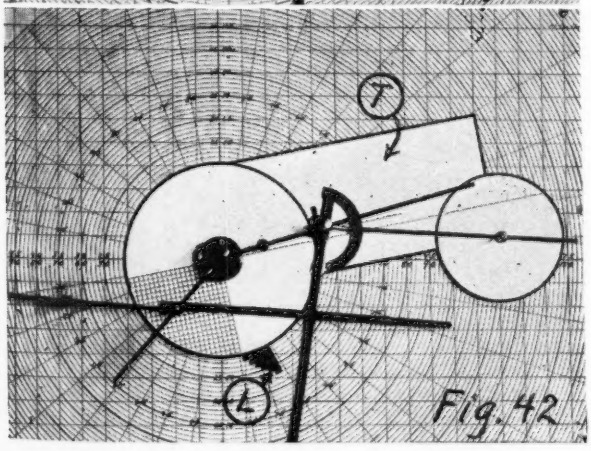


Fig. 41. Drafting board apparatus for illustrating the effect of adjustment and operating-condition changes upon the potential stability of the tractor

43. The final goal of any study of soil dynamics, as related to traction, should be to determine the effect of soil and traction equipment characteristics upon the location, direction and magnitude of the soil reactions against the wheels.

Even a superficial study of the above conclusions indicates that the design of a tractor is largely a matter of compromise. For example, the greatest possible clearance between all parts of the frame and the soil is very desirable. However, a large clearance means a high drawbar and a high center of gravity, both of which are undesirable. Thus if the designer is to make a wise compromise he must have a clear understanding of all factors involved, including the working conditions under which the tractor is to be used. If the operator is to get the best service from the tractor, he must have a knowledge of the effect of each of the possible hitch and weight location adjustments, in order that he may be able to make those adjustments which will most nearly adapt the tractor to the immediate working conditions.

Lecture Demonstration Apparatus

There are many facts in connection with the dynamic behavior of a tractor which are clearly evident to the man who is thoroughly trained in the methods of analytical mechanics and vector diagrams, but which are very difficult for most laymen and even some engineering students to understand. Figs. 38 to 40 show a rather crude apparatus which has, however, proved quite effective in demonstrating to the "practical man" most of the kinematic and dynamic factors influencing the behavior of a wheel-type tractor.

Figs. 41 and 42 illustrate a drafting board apparatus with which it is also possible to illustrate rather clearly the effect of various adjustments and operating-condition changes upon the probable stability of any tractor of which the necessary dimensions are known. Considering O of Fig. 41 as the center of the rear axle, G may be located to represent the center of gravity by choosing the proper scale and using either the rectangular or polar coordinates depending upon which dimensions of the tractor are known. Using the rectangular coordinates, D may be properly located to represent the front axle, B to represent the true point of hitch to the tractor, and H to represent the true point of hitch to the implement. The effect of placing either the front or rear wheels in a depression or on a ridge may be obtained by raising or lowering D the proper amount. The effect of placing the implement in a depression or on a ridge may be obtained by lowering or raising H the proper amount. The effect of a grade may be obtained by placing W at the proper angle with the vertical lines by means of the protractor. For any given position of the tractor and hitch adjustment the line of action of the load resistance is determined by P and the line of action of the weight of the tractor is determined by W. The moment arms of the load resistance and tractor weight are represented to scale by the perpendicular distances from the assumed point of intersection of the supporting and tractive soil reactions (C) to P and W.

The situation may be made still more apparent by drawing to scale and cutting out a tractor (T) and movable lug segment (L) and mounting as shown in Fig. 42.

Bibliography

1. E. R. Hewitt and D. L. Arnold—Principles of the Wheel Type Farm Tractor, Trans. of Soc. Aut. Engrs., Vol. 14, Part 1, pages 83-98, 4 figures, 1919.
2. G. W. Dunham—Artillery Motorization, Trans. of Soc. Aut. Engrs., Vol. 15, Part 1, pages 645-678, 26 figures, 1920.
3. A. F. Moyer—Tractor Weight and Drawbar Pull, Trans. Soc. Aut. Engrs., Vol. 15, Part II, pages 726-732, 4 figures, 1920.
4. H. W. Adams—Common Sense Instructions on Gas Tractor Operation, pages 209-211, 4 figures, 1920.
5. F. B. Seely and H. E. Ensign—Analytical Mechanics for Engineers—1921
6. A. H. Hoffman—A Study of Sidedraft and Tractor Hitches—University of California Bulletin No. 349—1922; The Tendency of Tractors to Rise in Front; Causes and Remedies—University of California Circular No. 267—1923.

Graphic Analysis as Applied to the Study of Wheel-Type Tractors*

By Joseph N. LeConte[1]

IN HIS series of articles on the "Kinematics and Dynamics of the Wheel-Type Farm Tractor," Mr. McKibben has used an analytic analysis exclusively. While this is certainly the most thorough and complete way to handle the problem, there are, nevertheless, certain advantages of graphic analysis which should not be overlooked. The principal advantage is the ease with which the effect of changes of conditions can be seen. The method is a simple one also, and, if drafting facilities are available, the quickest.

Consider a tractor traveling up a grade with a load, and moving with a uniform velocity as shown in Fig. 1. The problem is then a static one, since the acceleration of the center of mass is zero, and the external force system will be in equilibrium. In the ultimate, there are but three external forces acting upon the tractor, its weight acting vertically through the center of gravity, G, the drawbar pull, P_o, acting through the point, B, and the ground reaction, R. If the first two of these are known in direction, their point of concurrence, A, is fixed, and the third force, R, must pass through it. The weight, W, is known in magnitude and direction. If the drawbar pull, P_o, is known in magnitude as well as in direction, in other words, if the tractor is hauling a given load, the ground reaction, R, is completely determined by simply completing the parallelogram of forces at A. This is best done in a separate vector diagram to one side as in Fig. 1A. The method of procedure would be to lay off a line, de (Fig. 1A), whose length to any convenient scale represents the total weight of the tractor. At the lower end of this lay off the line, ef, to represent on the same scale of drawbar pull, P_o, drawing both of these vectors parallel to their actual positions in Fig. 1. Then the closing line, fd, will represent the resultant ground reaction, and it may now be transferred to Fig. 1 by drawing it parallel to its position in Fig. 1A, and through the original point of concurrence, A. It is evident that R is the resultant of R_1, R_2, R_3, R_4, R_5 and R_6 of Mr. McKibben's diagrams.

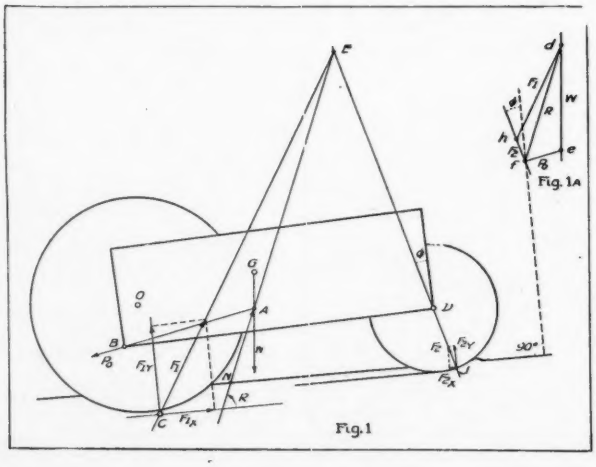
This resultant ground reaction can now be broken up into the two wheel reactions, F_1 and F_2. Beginning with the reaction F_2 under the front wheel, we know that it must pass through D, the center of the front axle. Its direction must also be known, and this will depend upon the nature of the soil over which the front wheel is rolling. If the surface is hard and smooth, the direction is at right angles to the road surface. If not, it will make an angle, ϕ, with this normal, always tipping backwards if the tractor is moving forwards, or in general tipping in a direction reversed from that of motion. This angle, ϕ, may be regarded as a "friction angle" as defined in works on practical mechanics. If it is known or assumed, the point of concurrence, E, is determined by producing the direction of F_2 drawn through D to meet R produced (Fig. 1). Then the reaction of the rear wheel, namely F_1, must pass through E, and also through C, this latter being the point under the rear wheel defined as in Mr. McKibben's paper. The vector diagram for constructing the magnitudes of F_1 and F_2 can be incorporated in Fig. 1A, where R is already shown. Draw through f a line, fh, parallel with DE, and through d a line, dh, parallel with CE. The intersection of these at h gives fh = F_2 and hd = F_1. These can now be transferred to Fig. 1, where they are represented in their true positions. Finally each of these can be broken up into components along and at right angles to the road, yielding F_1x and F_1y for the rear, and F_2x and F_2y for the front wheel. F_1x is the resultant (here the algebraic sum) of R_1 and R_4 of Mr. McKibben's diagrams, and F_1y is the resultant of R_2 and R_3. F_2x is the same as R_6, and F_2y the same as R_5.

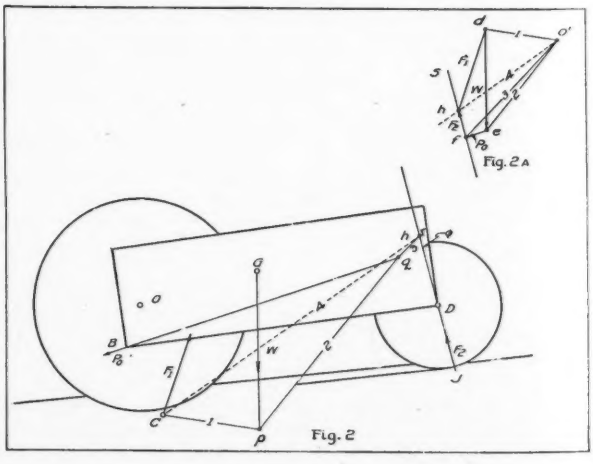
An inspection of the figure shows that the first point of concurrence, A, is always conveniently located for graphic construction as just explained. The second point, E, may, however, come at an inconvenient distance when R and F_2 are nearly parallel. In that case the funicular polygon may be used to advantage. In order to illustrate its use consider the tractor operating with small drawbar pull and with a small friction angle, ϕ, as in Fig. 2 Complete the partial vector diagram, def (Fig. 2A). Then from any convenient point O' as a pole draw the line of O'd, O'e, and O'f, numbering them 1, 2 and 3 for convenience, and draw the indefinite line, fs, parallel to F_2. Then returning to Fig. 2, draw Cp parallel to 1, intersecting w at p, draw pq parallel to 2, intersecting P_o produced at q, and draw qr parallel to 3, intersecting F_2 produced at r. Now connect r and C by the dotted line 4, and transfer it parallel to its original position to Fig. 2A. Where it intersects fs at h will give fh = F_2, and hd = F_1.

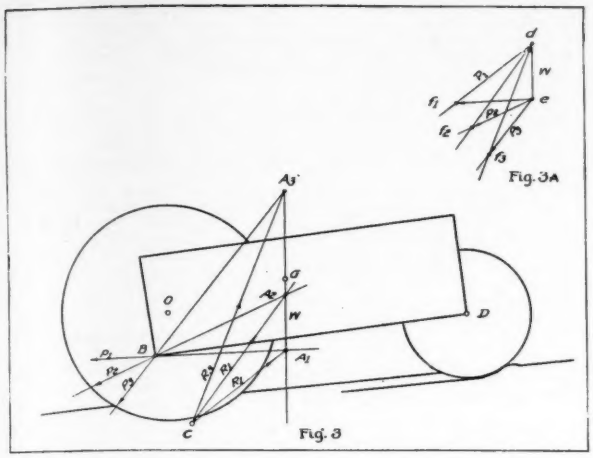
If the vector R (Fig. 1) cuts the ground line at a point, N, which lies between C and J, the tractor is in stable equilibrium. If R passes through C we have a limiting case, and the tractor is on the point of turning over backwards. If R passes to the rear of C the problem is impossible, as the force, F_2, changes from compression to tension. The condition where R just passes through C is therefore a criterion

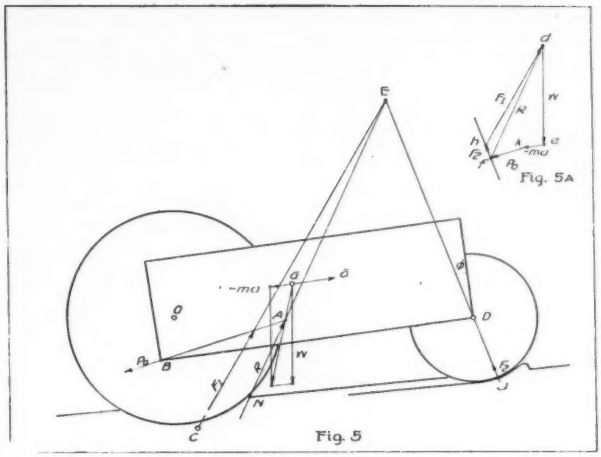
*Discussion of the paper, entitled "Kinematics and Dynamics of the Wheel-Type Farm Tractor," by E. G. McKibben, which appeared as a series of seven articles in the January to July (1927) issues of AGRICULTURAL ENGINEERING. Presented before a meeting of the Pacific Coast Section of the American Society of Agricultural Engineers, San Francisco, Calif., May, 1927.

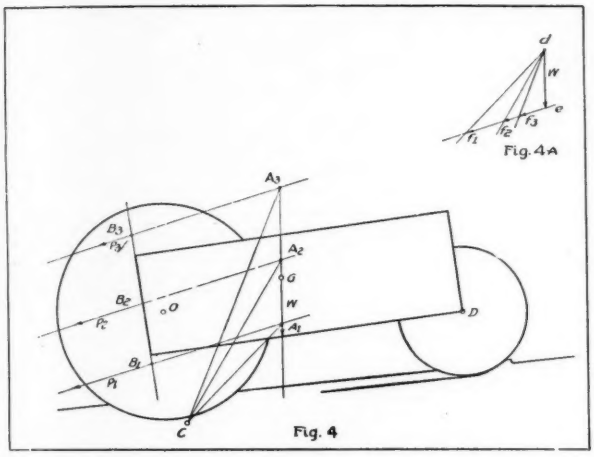
[1]Professor of engineering mechanics, University of California.











of stability, and under these conditions the front reaction, F_2, reduces to zero. The vector diagram drawn under this limiting condition will show the various relations between the magnitude, direction and line of action of P_o such that with a given weight, the structure will be on the point of overturning. First let the point of attachment, B, of the drag link remain fixed, while the direction of P_o is varied as in Fig. 3. Then the vector diagrams will be as in Fig. 3A, and P_1, P_2, and P_3 will be critical values of P_o. Again let the direction of P_o remain fixed while the point of attachment is shifted as in Fig. 4. Then the overturning forces P_1, P_2, and P_3 are given by ef_1, ef_2, and ef_3 in Fig. 4A.

If the tractor is moving with straight line motion but not at constant velocity, the effect of the linear acceleration, a, can easily be taken into account in all the preceding analysis, for, though the external force system is not now in equilibrium, it can be brought into that state by adding another force acting through the center of mass parallel with the road, equal in magnitude and opposite in direction to ma. (This is not exactly true, as the tractor with its wheels does not constitute a rigid body.) Here m is the mass of the tractor or its weight divided by g, the gravitation constant. Now this last vector is concurrent with the weight at G, and may be combined vectorially with it. In other words, the problem can be handled exactly as before, if instead of w we use the resultant of w and $w - \frac{a}{g}$. The complete solution of the problem shown in Fig. 1, but where G has positive acceleration, is drawn in Fig. 5. The effect of acceleration in the direction of motion is seen to reduce the stability, by shifting N nearer to C.

Irrigation Drainage by Pumping

WHEN large areas of land are brought under irrigation, says the department, the excess water applied to fields, together with that lost by seepage from canals and ditches, frequently causes the ground water to rise so high as to render much of the land unfit for cultivation. The drainage of such water-logged lands is usually accomplished in a manner similar to the drainage of wet lands in humid regions, that is, by the laying of tile lines or the excavation of open drainage ditches.

In the Salt River Valley of Arizona, however, it was found that the water-logged areas could be more effectively drained by sinking numerous wells and pumping the water into irrigation canals or returning it to the river. This method of drainage is described in Department Bulletin 1456-D, entitled "Drainage by Pumping from Wells in the Salt River Valley, Arizona," just issued by the U. S. Department of Agriculture.

The conditions in this valley were peculiarly favorable for drainage through wells since about half of the irrigated area is underlaid by a coarse, water-bearing formation consisting of gravel and bowlders known to be more than 150 feet thick in places, which readily yields large quantities of water. Moreover, there is available an abundance of cheap electric power for the operation of the pumps. A still further advantage is the fact that the pumped drainage water can usually be used for irrigation purposes for which there is a good demand.

The Salt River Valley Water Users' Association, which operates the system, began to sink wells for drainage in 1918 and by the close of the 1923 irrigation season about one hundred plants were in operation. As a direct result the area under which the water was within 10 feet or less of the surface was reduced from 64,200 acres in 1918 to 17,662 acres in 1923 and on practically all parts of the project the water had been lowered sufficiently to permit the land to be cultivated.

A large number of test wells were sunk in order to study the effect of pumping on the ground water. From these test wells it was found that the pumped wells lowered the water table for a distance of one-fourth mile to one mile depending on the character of the water-bearing strata.

The entire cost of the drainage system was slightly over a million dollars which was paid by a flat assessment of $5.20 per acre levied on all the land of the project. The yearly operating cost of the pumping plants is approximately 30 cents per acre.

Although the peculiar conditions of the Salt River Valley were especially favorable to drainage by pumping from wells, it is believed other localities where somewhat similar conditions exist may secure valuable suggestions from a study of the bulletin referred to.

Agricultural Engineering Digest

A review of current literature on agricultural engineering by R. W. Trullinger, specialist in agricultural engineering, Office of Experiment Stations, U. S. Department of Agriculture

Ultraviolet Spectroscopy of Engine-Fuel Flames, G. L. Clark and A. L. Henne (Journal Society of Automotive Engineers, 20 (1927), No. 2, pp. 264-269, figs. 2).—Studies conducted at the Massachusetts Institute of Technology are reported in which details are given of the method of control of the engine so that quantitative and reproducible measurements of detonation and comparisons with spectra can be made. Typical data are presented with photographs of the free-burning flames of hydrogen, carbon monoxide, methane, gasoline in a blowtorch, and the like. The outstanding result obtained was that during detonation the first quarter spectrum extends far into the ultraviolet and that of the second quarter a somewhat less distance, the third and fourth quarters being characterized by very little radiation energy. During normal explosion or when knock suppressers, irrespective of their chemical nature, are used in the engine under detonating conditions the spectra of all four quarters have the same length and essentially the same intensity. Lead emission lines from tetraethyl lead appear only in the first quarter. This is taken to indicate that the action of an antiknock material occurs throughout the mixture rapidly, probably by thermal decomposition ahead of the explosion wave. The ultraviolet spectra show that all substances which act as knock suppressers have precisely the same effect, in that in their presence there is no emission in the far ultraviolet, such as occurs in detonation, and the energy liberated is distributed throughout the whole stroke instead of largely in the first quarter.

Testing Draft Horses, E. V. Collins and A. B. Caine (Iowa Station Bulletin 240 (1926), pp. 193-223, figs. 27).—The development of methods and apparatus for testing the pulling power of horses is outlined, and the results of actual draft tests are presented and discussed in the first part of the publication. A second part presents the results of a study of the horse as a motor.

The experiments as outlined required a steady, constant pull, and the load did not vary either going up or down small hills. Two years studies demonstrated clearly that it is possible for horses weighing from 1,500 to 1,900 pounds or more to continuously exert one horsepower or more for periods longer than one day. It is also possible for a well trained horse to exert an overload of over 1,000 per cent for a short time.

Daily observations of horses working during all kinds of summer weather indicated that humid days are much harder on them than dry, hot days. The correct fitting of collars and the proper care of shoulders are also essential if maximum work is to be obtained. If it is necessary to work horses hard during rainy weather, housings should be provided to keep the collars and shoulders as dry as possible.

Three years of experimental work also demonstrated that it is possible for horses to exert a tractive effort of from one-tenth to one-eighth of their own weight, and to travel a total of twenty miles per day without undue fatigue.

The Dutch Oven or Cement Brooder Stove, H. B. Carroll, Jr., and E. B. Hillier (Pullman: Washington State College Extension Service, 1926, pp. [6], figs. 6).—The Dutch oven or cement brooder stove is described and illustrated.

Applications of X-Rays in the Automotive Industry, G. L. Clark, R. H. Aborn, and E. W. Brugmann (Journal of Society of Automotive Engineers, 20 (1927), No. 2, pp. 291-304, figs. 22).—Studies conducted at the Massachusetts Institute of Technology are reported which included a resume of X-ray science and of experimental results regarding practical applications to the examination of automotive materials. Special attention is devoted to the detection of imperfections in castings, the development of improved casting technique, the substitution of casting for forgings, and the X-ray examination of valves and other parts.

Water Gain and Allied Phenomena in Concrete Work, H. J. Gilkey (Engineering News-Record, 98 (1927), No. 6, pp. 242-244, figs. 3).—The results of studies conducted at the University of Colorado are briefly reported which showed that the phenomenon of gaining water is a natural one, occurring in dry concrete mixtures as well as in wet ones. It results from an effort of the solids to sink to the lowest possible position. After the concrete has been poured and working has ceased, this settling will continue until the mass starts to stiffen and the displaced water will rise. It is considered likely, therefore, that in attempting to control the workability of the mixture by the insertion of a workability clause, such as the designation of the slump or the flow, such designation should apply to the concrete in the forms instead of to that at the mixer.

Artificial Lighting for Poultry Houses, H. E. Cray (Ohio Agricultural College Extension Bulletin 56 [1926], pp. 16, figs. 6).—The results of experiments on the artificial lighting of poultry houses to increase egg production are reported, and information is presented on the proper equipment for this purpose.

It has been found that electric light is the most efficient, easiest to operate, and best all-round kind of light for poultry houses. One 40-watt bulb should be used for each two hundred square feet of floor space, and the lights should not be placed more than ten feet apart.

The best results have been secured by using reflectors as they intensify the light on the floor. The reflector should be sixteen inches in diameter and cone shaped, with the cone four inches high at the center. For best distribution of light when reflectors are used, the lights should be suspended six feet from the floor, ten feet apart, and half way from the front of the dropping board to the front of the house.

It is stated that the available data, while quite limited, indicate that on farm lighting plants the cost of operation is about five cents per bird for the winter period.

The Tractor on California Farms, L. J. Fletcher and C. D. Kinsman (California Station Bulletin 415 (1926), pp. 35, figs. 27).—The purpose of this bulletin is to aid the farmers of California in the choice and successful operation of their field power and to impress upon manufacturers and dealers the need of supplying tractors of the proper design and type to meet the special requirements for farming in California. The information presented is based on data obtained from replies to questionnaires sent to all known tractor owners in the state and from contact with tractor owners.

Detonation Specifications for Automotive Fuels, G. Edgar (Journal of Society of Automotive Engineers, 20 (1927), No. 2, pp. 245, 246).—It is pointed out that to draw detonation specifications for fuels a reproducible primary standard fuel must be developed and methods of comparing fuels must be agreed upon. The composition of gasoline is so complex and the knocking characteristics of its different constituents are so varied that great difficulty has been encountered in finding one or more hydrocarbons, the purity of which could be definitely established by test and which would thus be absolutely reproducible. Two hydrocarbons are cited that seem to be ideally suited for standard reference fuels, namely, pure normal heptane, $C_7 H_{16}$, and pure octane, $C_8 H_{18}$, which is prepared synthetically from tertiary butyl alcohol. By mixing these two hydrocarbons in different proportions it has been found possible to duplicate the knocking characteristics of any commercial fuel between the limits of 60 per cent of heptane and 40 per cent of octane and 40 per cent of heptane and 60 per cent of octane.

Dairy-Stable Ventilation, F. L. Fairbanks and A. M. Goodman (New York Agricultural College (Cornell) Extension Bulletin 151 (1926), pp. 35, figs. 26).—Practical information on the planning and construction of ventilation systems for dairy stables under the climatic conditions prevailing in the State of New York is presented, together with diagrammatic illustrations and working drawings. Descriptions are given of different systems of dairy stable ventilation, including especially the King and Rutherford and modifications thereof.

House the Hen Efficiently and Economically, J. G. Halpin, J. B. Hayes, and N. S. Fish (Wisconsin Agricultural College Extension Circular 184 (1925), pp. 19, figs. 18).—Practical information on the planning of poultry houses for Wisconsin conditions is given, together with working drawings and bills of material.

Colony Houses for Poultry, J. G. Halpin, J. B. Hayes, and J. Swenehart (Wisconsin Agricultural College Extension Circular 208 (1926), pp. 8, figs. 3).—Practical information on the planning and constructoin of colony houses for poultry adapted to Wisconsin conditions is presented, together with working drawings and bills of material.

Agricultural Engineering and Its Place in Canadian Agriculture, L. G. Heimpel (Scientific Agriculture, 6 (1925), No. 2, pp. 41-46, fig. 1).—In a contribution from Macdonald College, Quebec, an analysis is presented of the field of agricultural engineering in Canadian agriculture, special attention being drawn to the relation of this work to practically all of the recognized branches of agriculture. Special attention is drawn to the factors limiting the development of the work in Canada.

Observations on the Michigan Septic Tank, O. E. Robey (Michigan Station Quarterly Bulletin, 9 (1926), No. 1, p. 22).—A brief report of an examination of a tank in operation since 1915 and one in operation since 1918 is presented. The results indicate that a septic tank will work satisfactorily when near the surface, and that the tile system may be shallow even under somewhat adverse conditions.

Tests of Agricultural Machines, M. Ringelmann (Annals de la Science Agronomique Francaise et Etrangere, 43 (1926), No. 1, pp. 35-44).—Methods of testing agricultural machines and of mechanical experimentation followed in the station for testing machines of the National Institute of Agronomy of France are briefly described.

Flow of Heat in Pistons, H. A. Huebotter and G. A. Young (Purdue University, Engineering Experiment Station Bulletin 25 (1925), pp. 119, figs. 67).—Studies are reported, the purpose of which was to establish the optimum distribution of metal in the trunk type of piston for thermal conductivity from the head to the cylinder wall.

The results showed that the head of uniform section is the best conductor of heat, and that the short barrel of tapered section is the best dissipator of heat. A head section thick at the circumference will assist in the dissipation of heat, and for this reason a large fillet is recommended at the junction of the head and the barrel. The addition of metal to the head was found to lower the maximum temperature more than the same volume of metal applied to the barrel. The barrel should be as thick as the head section at the head end and as thin as practicable at the open end.

Ribs, when properly designed, were found to improve the conductivity more than an equal quantity of metal added to either the head or the barrel. The proportions of the head, the barrel, and the ribs are mutually dependent for best performance. The triangular rib, extending from the center of the head to midway the length of the barrel, is the most effective. A large number of thin ribs were found to be superior to a few ribs of the same total thickness, since this arrangement gives better heat distribution over the head and the barrel.

Between 60 and 85 per cent of the total heat was found to be dissipated from the ring belt in the usual type of piston. The conventional ring belt is about 60 per cent as effective as the piston skirt in dissipating heat with the same temperature difference. It was found that the ring belt should be as short as possible, and that a broad bearing land within the ring belt will improve the heat emission.

The results showed further that piston rings which make good thermal contact with the piston should be used for maximum cooling, and that a gray iron piston head section should be designed for conductivity rather than for strength. Gray iron should be fine grained and homogeneous for thermal conductivity, and low density, low coefficient of expansion, and high coefficient of conductivity should characterize the piston material.

Dust Respirators: Their Construction and Filtering Efficiency, S. H. Katz, C. W. Smith, and E. G. Meiter (U. S. Department of Commerce, Bureau Mines Technical Paper 394 (1926), pp. IV + 52, pl. 1, figs. 28).—This paper describes representative types of dust respirators, and presents the results of laboratory tests to determine their filtering efficiencies and resistances to air flow.

It was found that the efficiencies of the industrial dust respirators in restraining tobacco smoke ranged from 5 to 33 per cent when the air is passed at the rate of thirty-two liters per minute. A gas mask canister with two filters of absorbent cotton showed 63 per cent efficiency. A flat felt filter was most efficient, showing 97 per cent. The efficiencies against silica dust floated in air ranged from about 9 to 70 per cent for the dust respirators.

Filters of various fabrics, including cheesecloth, canton flannel, unbleached muslin, closely woven bleached muslin, filter paper, and absorbent cotton, all made so as to expose exactly one hundred square centimeters of filter area, were tested against tobacco smoke and silica dust in air flowing at the rate of ten liters per minute. Each material was tested in a single layer and in multiple layers. The results showed that each layer of fabric removes about the same proportion of smoke or dust that penetrates to it before the filters become clogged or altered by deposits of an arrested material. Consequently, when the efficiency of a single ply of a filter is known, the efficiency of any multiple ply filter of that material may be calculated.

It was found that silica dust clogged filters rapidly and increased the resistance to air flow, but some materials were more resistant to clogging than others. The dense filters of paper or closely woven muslin clogged most rapidly. Filters of loose texture, like cheese cloth or absorbent cotton, clogged the least. The efficiencies of the filters were increased by clogging with dust until eventually many filters gave an efficiency of 100 per cent. Woolen fabrics proved to be no better filters than cotton fabrics of similar texture.

The efficiency of the filters decreased somewhat with an increase in the rate of air flow. The resistance of the filters to air flow increased in proportion to the number of plies of fabrics after the first ply. The first filter layer showed a somewhat higher resistance than the additional ones. It was found that air filters of high efficiency can be made with a sufficient number of plies of material that has a low efficiency per single ply. Such filters have less resistance to air flow than equally efficient filters made of fewer plies of the higher efficiency materials. The thicker filters of loose textured material clogged less rapidly than equally efficient filters composed of fewer plies of tightly woven materials.

A new type of dust respirator was designed and constructed according to the principles brought out in the tests which consists of a large filter of canton flannel. At an air flow of eighty-five liters per minute the efficiency of this respirator was 93 per cent against silica dust.

Action of Sodium and Magnesium Sulfates on Portland Cement, G. R. Shelton (Industrial and Engineering Chemistry, 18 (1926), No. 8, pp. 854-856, figs. 2).—Studies conducted at the University of Saskatchewan on the effect of sodium and magnesium sulfate solutions on commercial and white portland cements to determine the action on portland cement clinker and on its compounds taken separately are reported. White portland cement made by heating to a higher temperature an intimate mixture of powdered marble, alumina, and flint in the proper proportions contained tricalcium aluminate, tricalcium silicate, and β— dicalcium silicate.

The reactions of the white cement were different from those of commercial cement when both were similarly treated with solutions of sodium and magnesium sulfates. An instance of this difference was the appearance of gypsum in the tests with crystalline commercial cement but not in the tests of white crystalline cement. Again the reaction products of white cement with sulfates were more like those of the pure cement constituents than were the products formed in the case of commercial cement.

The difference in character of hydrated cements was very apparent, fine sulfo aluminate needles being abundant in the hydrated commercial cement, while none were found in the white cement. The crystalline grains, as centers of gelatinous particles, lasted for a much longer time in the white cement than they did in the commercial cement. The presence of silicates seemed to have influenced the speed of disintegration of hydrated tricalcium aluminate crystals, since in the tests with the two varieties of cement and solutions of sodium sulfate these crystals lasted for a much shorter time than they did in the tests with pure hydrated tricalcium aluminate. Solutions of magnesium sulfate were especially destructive in their action on crystals of hydrated tricalcium aluminate, regardless of the presence or absence of calcium silicate.

The characters of the layers surrounding crystals of hydrated lime varied with the sulfate solutions used. In sodium sulfate the layers were apparent only on the edges of the lime crystals and were made up of granular masses. In magnesium sulfate solutions the lime crystals were heavily enveloped, the coating frequently consisting of a transparent homogeneous layer as well as granular masses.

A Preliminary Experiment on the Supporting Strength of Culvert Pipes in an Actual Embankment, M. G. Spangler (Iowa Engineering Experiment Station Bulletin 76 (1926), pp. 31, figs. 23).—The results of a preliminary study conducted in cooperation with the U. S. Dept. of Agr. Bureau of Public Roads to determine for different kinds of culvert pipe, embankment materials, and field conditions the ratios between the supporting strengths which culvert pipe can safely be counted upon to develop in actual use and the laboratory strengths of such pipes when tested by standard methods are reported.

Ten sections each 23.5 inches long of practically unreinforced 36-inch concrete culvert pipe with shields 3 inches thick were tested in an embankment which was built up gradually to a height of 10 feet above the top of the pipe. The measurements of side pressures were made by the use of six earth pressure cells.

Laboratory tests were also made of five similar pipes using three-edge bearings. The culvert pipes cracked under heights of embankment ranging from 4 to 8.5 feet above the top of the culvert, but none of the pipes collapsed or deformed extensively under the loads imposed by an embankment 10 feet high above the top of the culvert. The settlement of the rigid culvert pipes was many times greater than any lowering of their tops from shortening of their vertical diameters under the loads. The ratio of actual supporting strength to three-edge bearing laboratory test strength was approximately 2.6 at first crack in this experiment. Without the help of the active side pressure the ratio would have been about 1.9. The side pressure varied widely, showing a range equal to 158 per cent of the smallest result. However, the results confirmed the conclusion previously reached by the station that the active horizontal pressure in a mass of granular materials can be computed with fair accuracy by Rankine's formula for horizontal earth pressures.

Handbook on Construction and Maintenance of the National Forests' Telephone System (U. S. Department of Agriculture, Forest Service, 1925, pp. V + 126, figs. 93).—The purposes of this handbook are (1) to set forth certain broad policies, (2) to describe certain approved types of telephone construction and maintenance (including installation of instruments) and to establish standard specifications for the more important types, (3) to explain briefly the fundamental principles involved in the operation of telephone lines and instruments, (4) to furnish instructions for locating and clearing trouble, and (5) to describe special methods used and practices followed in different districts which are adaptable to the varying field conditions.

Factors Influencing Soil Moisture Regulation

(Continued from page 186)

36. Shaw, C. F. The effect of a paper mulch on soil temperature. (Hilgardia [California Sta.], 1 (1926), No. 15, pp. 341-364) (E. S. R., 55, p. 316).

37. Stewart, G. R. Some effects of mulching paper on Hawaiian soils. (Soil Sci., 22 (1926), No. 1, pp. 35-39).

38. California Sta. Rpt. 1924, p. 47. (E. S. R., 53, p. 419).

39. Call, L. E., and Sewell, M. C. The soil mulch. (Jour. Amer. Soc. Agron., 9 (1917), No. 2, pp. 49-61). (E. S. R., 37, p. 212).

40. Fraps, G. S. Moisture relations in some Texas soils. (Texas Sta. Bul. 183 (1915)) (E. S. R., 34, p. 816).

41. Thomas, E. E. Studies on the irrigation of citrus groves. (California Sta. Bul. 341 (1922)) (E. S .R., 47, p. 538).

42. McCall, M. A., and Holtz, H. F. Investigations in dry farm tillage. (Washington Sta. Bul. 164 (1921)) (E. S. R., 46, p. 216).

43. Cardon, P. V. Tillage and rotation experiments at Nephi, Utah. (U. S. Dept. Agr. Bul. 157 (1915)) (E. S. R., 32, p. 525).

44. Burns, G. Soil moisture. (Yearbook Khediv. Agr. Soc., Cairo, 1905, pp. 265-272) (E. S. R., 18, p. 318).

45. Mendes de Godoy, J. Influence of cultivation on the conservation of water in the soil. (Escola Agr. "Luiz de Queiroz," Piracicaba, Brazil, Ser. Agr., Bol. 4 (1919)) (E. S. R., 42, p. 514).

AGRICULTURAL ENGINEERING

Established 1920

A journal devoted to the advancement of the theory and practice of engineering as applied to agriculture and of the allied arts and sciences. Published monthly by the American Society of Agricultural Engineers, under the direction of the Publications Committee.

PUBLICATIONS COMMITTEE

R. W. Trullinger, Chairman

J. B. Davidson F. A. Wirt

G. W. Iverson P. S. Rose

The Society is not responsible for the statements and opinions contained in the papers and discussions published in this journal. They represent the views of the individuals to whom they are credited and are not binding on the Society as a whole.

Contributions of interest and value, especially on new developments in the field of agricultural engineering, are invited for publication in this journal. Its columns are open for discussions on all phases of agricultural engineering. Communications on subjects of timely interest to agricultural engineers, or comments on the contents of this journal or the activities of the Society, are also welcome.

Original articles, papers, discussions, and reports may be reprinted from this publication, provided proper credit is given.

RAYMOND OLNEY, Editor

Agricultural Production Costs

PRODUCTION costs on American farms must come down. Our best farmers know it. The agricultural leaders know it. Business men—manufacturers, bankers, insurance executives, etc.—all know it. It is common talk in well-informed circles.

Agriculture can no longer depend on prices alone to yield a profit. The farmer has too long been at the mercy of prices, over which he has had little or no control. His profits, as in other lines of business, must come from lower costs.

There is another reason. American agriculture is facing a period of intense competition. It exists right now within our own borders—between producers of cotton, dairy products, and wheat, principally. But the most serious competition is in the world markets. It can be met effectively only by lower costs.

A similar situation faced manufacturing and transportation forty years ago. Out of it they have emerged the largest and most prosperous in the world.

But this result could never have been accomplished without engineering—engineering backed up by intelligent management and sound financing. It was not so much due to the introduction of labor-saving machines and methods as to their more efficient and more extensive application—a change from high-cost to low-cost methods. That is answer.

Agriculture cannot attain a parity with other industry until it also is engineered. Much progress has already been made in this direction but, as a matter of fact, the surface of this tremendous field has barely been scratched.

A summary of data from cost-of-production studies conducted by the U.S.D.A. Bureau of Agricultural Economics and state agricultural colleges and experiment stations indicates that power and labor make up 40 to 85 per cent of the total cost of production of such crops as corn, wheat, oats, and cotton. Other items of cost—including principally use of land, fertilizer and seed—are for the most part fixed.

The cost items of power and labor can be—are being—greatly reduced by time-saving machinery and methods. For example, G. W. McCuen, professor of agricultural engineering at Ohio State University, has for several years personally conducted an experiment in which he has proven that complete motorization of the corn crop is practical and economical. He has reduced the time necessary to grow and harvest an acre of corn from 26 to 5.77 man-hours.

There are many other just such outstanding examples of what engineering is doing to lower production costs in agriculture.

Engineering will do for agriculture what it has already done for manufacturing and transportation. Engineering, dealing as it does with labor, power, and materials, has much to do with agricultural production. It will put it on an industrial basis. The result will be larger profits and higher standards of living.

Engineering as applied to agriculture comprehends (1) a larger, more efficient, more economical use of mechanical power, machines, and materials; (2) the design and development of new machines and structures, or the improvement of present equipment; (3) the development of improved farming methods and practices; and (4) the reclamation and utilization of waste areas.

Achievements along these lines all result in lower costs. In competitive manufacturing the concern that reduces its cost the most is in position to make the most profit. The same thing must be true in agriculture.

It is the agricultural engineer's job not only to develop ways and means of lowering costs in the agricultural industry, but to demonstrate to farmers how it can be accomplished.

Going Ahead

WHAT shall we say of an organization that registers one-third of its membership at an annual meeting? Certainly the least we can say is that such a registration would indicate that the organization is blessed with an unusually responsive membership. It would also indicate that it has back of it a particularly worthy objective, and that it is making progress in the direction of accomplishing that objective.

The American Society of Agricultural Engineers, at its 21st annual meeting held last month at University Farm, St. Paul, Minnesota, registered one-third of its membership. Agricultural engineers are responsive. The Society is making progress. It is making exceptionally good progress—because it has back of it an unusual group of loyal, earnest, and capable members, who would be a distinct credit to any organization.

One writer, whose report of the meeting appears in a leading farm machinery publication, makes this significant statement:

"The meeting was characterized by a spirit of good fellowship, optimism, progress, and enthusiasm, for which agricultural engineers are noted—a spirit which is the marvel of visitors attending for the first time, but taken as a matter of course by those more familiar with this organization."

The manager of one of the largest commercial associations in the country is authority for the statement that the agricultural engineers, though many times fewer in numbers, have made a greater contribution to the development of a particular branch of that association's work than have been made by all other related technical groups to its entire field of activities.

The Society, therefore, is just what its members make it. And they are making it a virile organization, one that is making a real contribution to agricultural development in the new direction this development is taking. A.S.A.E. is going ahead.

Are We Ready?

ONE of the things attending an A.S.A.E. annual meeting does is to give one a new and broader outlook on the agricultural-engineering profession. The outlook for our profession is indeed bright. It would appear that we are on the verge of a tremendous development in our field. If this is true—and there is every reason to believe it is—it means enlarged opportunities. It also involves greater responsibilities. Are we ready to assume the latter that we may embrace the former? We believe we are. Certainly the profession is ready, if a properly qualified personnel means anything.

A. S. A. E. and Related Activities

The 21st Annual Meeting

AGRICULTURAL engineers probably do not realize how fast they are making history. However, anyone who attended the 21st annual meeting of the American Society of Agricultural Engineers, at University Farm, St. Paul, Minnesota, June 22 to 25, cannot help but be impressed with the fact that substantial progress has been made during the past year. The change of attitude with respect to agricultural engineering that is taking place is most significant. As a matter of fact, it would seem that the time is at hand when the agricultural engineer will need to spend less time in "selling" himself and the service he can render and will have a larger opportunity to devote his efforts to "engineering" agriculture. The increased recognition which agricultural engineering is receiving cannot help but be a source of real gratification to agricultural engineers. But most important of all, however, both to the profession and to those whom it serves, is the fact that the profession is manned by men whose integrity, ability and vision are unequalled in any field.

A number of things contributed to the splendid success of this year's A.S.A.E. annual meeting. The setting at University Farm and the arrangements and accommodations provided by the local committee were as nearly 100 per cent as it would be possible to make them.

The Meetings Committee deserves a great deal of praise for the splendid program provided. The best evidence of the interest and value of the program is the fact that all the sessions were not only exceptionally well attended, but there was very few who left before the close of the sessions.

One of the important features of the meeting was the attention given to rural electrification. On the day previous to the opening of the annual meeting, June 21, the annual meeting of the Committee on the Relation of Electricity to Agriculture was held at St. Paul, which was preceded by a day spent at the Red Wing rural electrification project. Simultaneous with this meeting were held the sessions of a group of men employed by the electric power companies in developing rural business and of the Committee of Rural Electrification Project Leaders of the A.S.A.E. Rural Electric Division.

The first day of the A.S.A.E. meeting featured the sessions of the Rural Electric and Reclamation Divisions. The rural electric session opened with a short address by the chairman of the Division, Arthur Huntington, on the contribution which the agricultural engineer is making to the agricultural industry and to farm life. This was followed by a report of the Committee on Wiring by B. P. Hess, chairman, and report of the Committee on Farm Lighting, by W. C. Brown, chairman.

A report which stimulated unusual interest was that on the feed grinding investigations at the University of Wisconsin, presented by W. C. Kreuger. E. A. Stewart, of the University of Minnesota, presented an interesting illustrated address on rural electrification in Europe.

A report by Miss Eloise Davison, of Iowa State College, chairman of the Committee on Household Appliances, and a report of T. E. Hienton, of Purdue University, chairman of the Committee on Correlation, completed the program of the morning session of this Division.

The afternoon program opened with the presentation of a paper prepared on the subject of farm refrigeration studies by W. T. Ackerman, of the New Hampshire Agricultural Experiment Station, followed by a discussion by E. C. Easter, of the Alabama Power Company. A paper of particular interest on the electric rural rate problem prepared by N. T. Wilcox, rate engineer of Stone & Webster, Incorporated, was next presented, followed by a discussion by E. R. Meacham, of the Wisconsin Power and Light Company, and by Mr. Holloway, of the Iowa Railway and Light Corporation. Perhaps the outstanding fact in connection with the study of the rate problem is that the material presented agreed as to the fundamentals of cost, but that different methods are employed in the application of these principles to the rate schedules.

G. C. Neff, general manager of the Wisconsin Power and Light Company, presented an interesting paper, entitled "Taking Power and Light to the Farmer." This was followed by a paper, entitled "Developing Methods and Equipment for Extending the Use of Electricity in Agriculture," presented by Charles H. Churchill, Jr., manager of the Fort Henry Branch of the New York Light, Heat and Power Company.

Concluding the program of the Rural Electric Division a committee consisting of members appointed by the chairman presented suggestions for next year's work.

One of the outstanding things about the program of the Reclamation Division was the evidence of the unusual activities of its committees during the past year. The session opened with the reports of several committees including the Committee on Drainage in Humid Regions by Q. C. Ayres, Iowa State College, chairman; Committee on Drainage of Irrigated Land (report presented by J. C. Marr); Committee on Soil Erosion (report presented by G. Muehleisen); Committee on Forestry by L. F. Livingston, chairman; Committee on Land Clearing by W. A. Rowlands, chairman; Committee on Irrigation by Geo. S. Knapp, chairman; Committee on Run-off from Agricultural Lands, by C. E. Ramser, chairman.

The technical papers presented at this session included a paper, entitled "Subsoil as a Factor in Drainage Design," by Dr. S. A. Norling, consulting agricultural engineer, which was discussed by E. R. Jones, University of Wisconsin; a paper, entitled "Silting of Drainage Ditches—Its Control and Prevention," by R. N. Towl, drainage engineer; a paper, entitled "Influence of Growth on Flow in Open Ditches," by C. E. Ramser, drainage engineer, U. S. Department of Agriculture, which was discussed by E. V. Willard, commissioner of drainage and waters of Minnesota; a paper, entitled "Alkali Land Reclamation," by J. C. Marr, associate U.S.D.A. irrigation engineer, which was discussed by M. R. Lewis, of the University of Idaho.

Following the afternoon session of the first day those in attendance at the meeting were entertained by a five-inning game of kittenball between the division of agricultural engineering of the University of Minnesota and student members of the Society in attendance at the meeting. The result of the game was very much in doubt until the last few minutes of play, when the "home team" ran up considerable of a score which placed them much in the lead. This game was followed by a picnic supper and entertainment in the main dining hall at University Farm.

Group meetings featured the evening of the first day and included meetings of the heads of college agricultural engineering departments, of a group of land clearing engineers, and of student members of the Society in attendance at the meeting.

The second day of the meeting was given over entirely to general sessions. The meeting was called to order by William Boss, chairman of the Meetings Committee, who introduced W. C. Coffey, dean and director, Department of Agriculture, University of Minnesota, who gave the address of welcome to agricultural engineers to the University and addressed the meeting on the subject of significant changes taking place in agriculture. Mr. Boss then turned the meeting over to President O. W. Sjogren, chairman of the department of agricultural engineering, University of Nebraska, who delivered the president's annual address.

Due to a sudden illness, Robert S. Pack, retiring president of the National Electric Light Association, scheduled to address the meeting, was unable to be present, but the high spots of his address were presented by Dr. E. A. White. This was followed by a review of the status and progress of agricultural engineering research during 1926 by R. W. Trul-

linger, specialist in agricultural engineering of the U.S.D.A. Office of Experiment Stations.

The afternoon session featured addresses by E. V. Willard, commissioner of drainage and waters of the State of Minnesota, on the economic and moral influence of drainage and flood control on the community, by L. W. Wallace, executive secretary, American Engineering Council, on engineering and agriculture, and by Roy E. Murphy, manager of Forestdale Farm, Burlington, Iowa, on solving the labor problem in farming operations.

On the same day the visiting ladies were delightfully entertained by the wives of local members. The features of this entertainment included a bus trip to Lake Minnetonka, a box luncheon at Minnetonka, a short boat trip on the Lake, and return via the river drive in buses provided for the purpose. Again in the evening a reception for the visiting ladies was given by the local ladies.

Following the general session three field demonstrations were given on University Farm, including a demonstration of the Iowa torque dynamometer, the Chase tractor guide, and the big-team hitch. The annual business meeting of the Society was held during the evening.

The third day was given over to simultaneous sessions of the Farm Power and Machinery and the Farm Structures Divisions. The program of the Farm Machinery Division featured a report on the progress and correlation of farm equipment research by H. B. Walker, senior agricultural engineer of the U. S. Department of Agriculture, in charge of the Department's survey of research in mechanical farm equipment; a report by J. B. Davidson, of Iowa State College, chairman of the Committee on Cost of Production, entitled "Analysis of Farm Production Costs from an Engineering Standpoint"; a paper on the kinematics and dynamics of the wheel-type farm tractor by E. G. McKibben, of the University of California; a paper on mechanical equipment for the cultivation of row crops by R. I. Shawl, of the University of Illinois; a paper giving the results of a preliminary study of the relation between form and power in the horse based on horse pulling contest data by A. E. Brandt, of Iowa State College, and a brief report by C. O. Reed, engineer in charge of the U.S.D.A. corn borer control campaign on the results of the corn borer clean-up.

The outstanding feature of the Farm Structures Division session was the discussion of the relation between the farm building overhead and cost of production. A paper on this subject was presented by John Swenehart, of the University of Wisconsin. The program was built around the discussions begun at a conference of farm structures men held in Chicago on March 22. In line with the Division's effort to get down to fundamentals on farm building problems an interesting report was presented by M. C. Betts, of the U. S. Department of Agriculture, on the promotion of research in farm structures. This was followed by a discussion led by W. G. Kaiser, of the Portland Cement Association, on developing a program of planned farm structure studies.

At 3:30 p.m. both sessions closed to permit those in attendance to take the inspection trip to the University experimental peat plots and to the Bowman Farm buildings. This trip also included a stop-over at the plant of the Minneapolis Steel & Machinery Company.

The annual banquet constituted the evening program of the third day. The banquets of the A.S.A.E. annual meetings have become delightful occasions when those attending the meetings turn from the serious technical programs to entertain and to be entertained. The annual banquet this year was no exception to the same delightful occasions of past meetings, and under the generalship of Dan Scoates, of the A. & M. College of Texas, who acted as toastmaster, it was quite obvious that " a good time was had by all."

The address of the evening was given by E. M. Freeman, dean of the college of agriculture, forestry, and home economics, of the University of Minnesota. Other speakers included O. W. Sjogren, retiring president, O. B. Zimmerman, incoming president, and William Boss, chairman of the Meetings Committee. The music and entertainment arranged for by the local committee was very much enjoyed. Dancing and cards followed.

The fourth and last day of the meeting was given over to an all-day session of the College Division. The meeting was opened with an interesting address by Dr. A. V. Storm, of the University of Minnesota, on recent developments in college instruction methods. Other papers included a paper on the possibilities and relationship of the college agricultural engineering departments to secondary school education by E. W. Lehmann, of the University of Illinois; a paper on logical policies for juvenile extension programs by I. D. Wood, of the University of Nebraska; and a paper on what agricultural engineers can contribute to home economics instruction by Eloise Davison, of Iowa State College. Brief reports by the chairman of committees of the Division were also a feature of the session. The session closed with educational demonstrations, including farm machinery laboratory instruction by the agricultural engineering faculty of Iowa State College and a rural sanitation project by E. A. Stewart, of the University of Minnesota.

The Resolutions Committee, consisting of F. A. Wirt, chairman, J. B. Davidson, E. W. Lehmann, and R. W. Trullinger, presented the following resolutions:

WHEREAS the Society has made great progress during the last year under the able leadership of President Sjogren and Secretary Olney,

RESOLVED that we take this means of expressing our appreciation for their splendid efforts on behalf of the American Society of Agricultural Engineers.

WHEREAS the success of the 21st annual meeting has largely been due to the splendid arrangements provided by the Meetings Committee and to the untiring efforts of Prof. William Boss and associates,

RESOLVED that we extend Prof. Boss and his colleagues our most sincere thanks.

WHEREAS all members and visitors, ladies as well as men, attending the 21st annual convention have been the recipients of a most delightful hospitality at the hands of the University of Minnesota,

RESOLVED that we express in this manner our appreciation for all that has been done for us.

WHEREAS the success of the program has been due largely to the generous cooperation of speakers in making the program of outstanding interest and value,

RESOLVED that we take this means of thanking them, especially the speakers outside of our membership. Particularly do we wish to mention Deans W. C. Coffey and E. M. Freeman, of the University of Minnesota, Secretary L. W. Wallace of American Engineering Council, and Dr. A. V. Storm of the University of Minnesota.

WHEREAS the vital need for a Bureau of Agricultural Engineering in the U. S. Department of Agriculture is of increasing importance, and

WHEREAS proper recognition can never be given the field of agricultural engineering until the U. S. Department of Agriculture recognizes the importance of the subject by creating a bureau out of the present division in the Bureau of Public Roads,

RESOLVED that we take this occasion to repeat the resolution sent to Secretary Jardine on February 2, 1927, as published on page 45 of the February issue of AGRICULTURAL ENGINEERING.

WHEREAS flood control in the Mississippi Valley is an acute national problem, and

WHEREAS water run-off from agricultural fields, drainage, and prevention of soil erosion are important factors in flood control measures, and

WHEREAS the American Society of Agricultural Engineers has within its membership many eminent specialists in these subjects,

RESOLVED that this organization offer its services to all governmental and state agencies where we can be of definite service in connection with water run-off, soil erosion, and agricultural engineering phases of this acute national problem.

WHEREAS the Bureau of Education of the U. S. Department of the Interior is planning a study of agricultural college education,

RESOLVED that our officers should call the attention of this bureau to the importance of an investigational personnel which will include person or persons competent to interpret all matters properly classified under agricultural engineering.

Division Organization

DURING the A.S.A.E. annual meeting in 1926, the officers of the Society decided to try out a plan proposed for the organization of the professional divisions. This plan provided for an executive committee of each division—except the College Division—to be comprised of the chairman, vice-chairman and the immediate past-chairman. It further provided that the chairman would serve only one year and would be automatically succeeded by the vice-chairman. Each incoming president of the Society, therefore, would simply appoint a new vice-chairman of each division. This plan is still on trial, but is proving so satisfactory that it will likely be adopted eventually as the fixed policy of the Society.

In accordance with this plan, the vice-chairmen succeeding to chairmanships of the divisions, following the annual meeting at University Farm, St. Paul, last month, are as follows:

Farm Power and Machinery Division—E. R. Wiggins, agricultural engineer, French & Hecht, Davenport, Iowa.

Rural Electric Division—E. A. White, director, Committee on the Relation of Electricity to Agriculture, Chicago, Illinois.

Farm Structures Division—W. G. Kaiser, agricultural engineer, Portland Cement Association, Chicago, Illinois.

Reclamation Division—Geo. S. Knapp, state irrigation commissioner, Topeka, Kansas.

H. B. Walker, professor of agrcultural engineering, Kansas State Agricultural College (temporarily serving as a senior agricultural engineer of the U. S. Department of Agriculture), has been reappointed by President O. B. Zimmerman as chairman of the College Division.

President Zimmerman has also appointed the following members to division vice-chairmanships:

Q. C. Ayres, assistant professor of agricultural engineering, Iowa State College—vice-chairman, Reclamation Division.

John Swenehart, professor of agricultural engineering, University of Wisconsin—vice-chairman, Farm Structures Division.

E. A. Stewart, associate professor of agricultural engineering, University of Minnesota—vice-chairman, Rural Electric Division.

L. J. Fletcher, agricultural engineer, Caterpillar Tractor Co.—vice-chairman, Farm Power and Machinery Division.

Personals of A.S.A.E. Members

D. L. Renner has resigned as general engineer of the Westinghouse Electric & Manufacturing Company to accept the position of rural service supervisor with the Nebraska Gast & Electric Company, Lincoln, Nebraska. For the past two years Mr. Renner has been handling rural electrification activities for the former company and his work will be along the same lines in his new connection.

I. F. Reed, a graduate assistant in the Department of Agricultural Engineering at Ohio State University, was married June 11 to Miss Beatrice Samson.

E. B. Sawyer has resigned as president of the Cushman Motor Works, Lincoln, Nebraska, and will establish himself in independent sales work and represent a few manufacturers in a sales capacity in California. Mr. Sawyer has been a prominent figure in the gasoline industry having been connected with the Cushman Motor Works for 18 years. On July 15 he will establish headquarters with the Coast Machinery Company, 464 E. Third St., Los Angeles.

Coming A.S.A.E. Meetings

North Atlantic Section—at Pittsburgh, Pa., October 12, 13 and 14, 1927.

Farm Power and Machinery Division—at Hotel Sherman, Chicago, November 29 and 30, 1927.

Farm Structures Division—at Hotel Sherman, Chicago, December 1 and 2, 1927.

Southern Section—at Memphis, Tenn., first week in February, 1928.

New A.S.A.E. Members

William C. Allen, editor, Farmstead, Stock & Home Co., Minneapolis, Minn.

H. T. Borsheim, chief engineer, Hart-Parr Company, Charles City, Iowa.

Armin Elmendorf, research engineer, The Celotex Company, Cihcago, Ill.

Alfred S. Grant, salesman, Minnesota Power & Light Co., Duluth, Minn.

U Po Han, importer of machinery, U. Po Han & Co., Rangoon, Burma.

Madge E. Johnson, research instructor, University of Arkansas, Fayette, Ark.

M. R. Lewis, head of agricultural engineering department, University of Idaho, Moscow, Idaho.

George Manikowske, president, Wind Electric Co., Minneapolis, Minn.

David Meeker, field engineer, Portland Cement Association, St. Louis, Mo.

Frederick C. Mensing, vice-president and treasurer, Groov-Pin Corporation, Chicago, Ill.

Graydon Oliver, technical editor, Petroleum World Publishing Co., Los Angeles, Calif.

Otto Schnellbach, Nash, Watjen & Banks, Ltd., New York, N. Y.

C. J. Scranton, Jr., designing engineer, Avery Power Machinery Co., Peoria, Ill.

Gilbert C. Skinner, general manager, St. Madeleine Sugar Co. Ld., Trinidad, B.W.I.

Edgar S. Stiles, manager, Peters Trust Company, Omaha, Neb.

John G. Sutton, drainage engineer, U.S.D.A. Bureau of Public Roads, Cape Girardeau, Mo.

John R. Taylor, operating manager, Campbell Farming Corporation, Hardin, Mont.

Transfer of Grade

James K. Alvis, student, Virginia Polytechnic Institute, Blacksburg, Va. (Student to Junior Member.)

Ralph U. Battles, student, Ohio State University, Columbus, Ohio. (Student to Junior Member.)

Robert D. Chew, student, Virginia Polytechnic Institute, Blacksburg, Va. (Student to Junior Member.)

Wilbur L. Fohl, corn borer inspector, U. S. Department of Agriculture, Middlebranch, Ohio. (Student to Junior Member.)

Wesley S. Green, student, Ohio State University, Columbus, Ohio. (Student to Junior Member.)

M. Greenler, student, Ohio State University, Columbus, Ohio. (Student to Junior Member.)

Stuart E. Haseltine, student, University of Illinois, Urbana, Ill. (Student to Junior Member.)

Max G. Hoagland, student, University of Illinois, Urbana, Ill. (Student to Junior Member.)

Harry P. Hummel, farmer, Union City, Ind. (Student to Junior Member.)

George L. Krohm, student, Ohio State University, Columbus, Ohio. (Student to Junior Member.)

Wilbur A. Miller, student, Ohio State University, Columbus, Ohio. (Student to Junior Member.)

Applicants for Membership

The following is a list of applicants for membership in the American Society of Agricultural Engineers received since the publication of the June issue of AGRICULTURAL ENGINEERING. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

Richard M. Atwater, Jr., consulting engineer, Scarsdale, N. Y.

John A. Bonell, assistant professor agricultural engineering, South Dakota State College, Brookings, S. D.

Michael M. Burris, landscape engineer, J. H. Holcombe, Inc., Trenton, N. J.

Frank P. Cartwright, civil engineer, National Lumber Manufacturers Assn., Washington, D. C.

Ralph H. Chestnutt, assistant agricultural engineer, Virginia Polytechnic Institute, Blacksburg, Va.

Jesse H. Choguill, vice-president and general manager, John Deere Plow Co., Syracuse, N. Y.

J. D. Clarkson, president, Ozark Development Company, West Plains, Mo.

Walter J. Clement, engineer in farm machinery department, The Bossert Corporation, Utica, N. Y.

Wilber A. Cochel, managing editor, Kansas City Star, Kansas City, Mo.

R. N. Cuykendall, manager ventilation department, James Manufacturing Co., Fort Atkinson, Wis.

R. K. Dallas, rural electrification, Ohio Edison Co., Springfield, Ohio.

E. R. Durgin, associate editor, Case "Eagle", J. I. Case Threshing Machine Co., Racine, Wis.

H. J. Ferris, vice-president, Hunt, Helm, Ferris & Co., Inc., Harvard, Ill.

Harry L. Garver, rural electrification investigator, State College of Washington, Pullman, Wash.

Clarence J. Hurd, assistant to project leader, Corvallis, Ore.

William Johnson, associate editor, Farm Life, Spencer, Ind.

Walter H. Lloyd, editor, The Ohio Farmer, Cleveland, Ohio.

E. R. MacIntyre, editor, The Wisconsin Farmer, Madison, Wis.

Daniel McKee, editor, Canadian Countryman Publishing Co., Toronto, Ontario, Canada.

J. L. McKitrick, engineer, W. P. Miller, Agricultural Engineer, Columbus, Ohio.

William E. Meek, Jr., salesman, John Deere Plow Co., St. Louis, Mo.

Arch S. Merrifield, editor, Farm Machinery and Hardware, St. Louis, Mo.

Arthur C. Page, commercial editor, Prairie Farmer Publishing Co., Chicago, Ill.

Ralph Prater, general manager, Prater Pulverizer Co., Chicago, Ill.

Homer S. Pringle, extension instructor, New York State College, Ithaca, N. Y.

Charles W. de Rekowski, consulting agricultural expert, Detroit, Mich.

Bruce Russell, architect, Clay Equipment Corporation, Cedar Falls, Iowa.

A. A. Thomson, editor, Canadian Farm Implements, Winnipeg, Manitoba, Canada.

John Thompson, editor, The Iowa Homestead, DesMoines, Iowa.

John W. Towle, civil engineer, Omaha Steel Works, Omaha, Neb.

Ernest W. Trussell, agricultural engineer, Mississippi Power Co., Gulfport, Miss.

R. D. Tufford, designer, Minneapolis Steel & Machinery Co., Minneapolis, Minn.

John T. Twells, chief engineer, Western Harvester Co., Stockton, Calif.

Theodore Uehling, field research work, Montgomery Ward & Co., Chicago, Ill.

L. E. Van Allen, local manager, West Penn Power Co., Greensburg, Pa.

Francis B. Wilson, salesman, Geo. W. Prising Co., Inc., San Francisco, Calif.

Grant Wright, editor and publisher, Eastern Dealer, Philadelphia, Pa.

Charles H. Young, consulting engineer, Central States Engineering Co., Muscatine, Iowa.

Transfer of Grade

Lawrence E. Best, farmer, Pattonsburg, Mo. (Student to Junior Member.)

M. W. Bloom, student, Liberal, Kansas. (Student to Junior Member.)

Major F. Mueller, student trainee, J. I. Case Threshing Machine Co., Racine, Wis. (Student to Junior Member.)

Employment Bulletin

This service, conducted by the American Society of Agricultural Engineers, appears regularly in each issue of AGRICULTURAL ENGINEERING. Members of the Society in good standing will be listed in the published notices of the "Men Available" section. Non-members as well as members, are privileged to use the "Positions Open" section. Copy for notices should be in the Secretary's hands by the 20th of the month preceding date of issue. The form of notice should be such that the initial words indicate the classification. No charge will be made for this service.

Men Available

AGRICULTURAL ENGINEER available. Seventeen years experience in the designing and manufacture of farm tractors, motor trucks, harvesting machines, and earth-working tools. Sales experience in United States, Canada, England, France, and Italy. Write for interview. MA-132.

AGRICULTURAL ENGINEER, graduate of University of Illinois, nine years teaching experience as assistant professor in one of the largest universities of the central west. Eleven years manufacturing experience with one of the large tractor and farm implement builders. Experienced in production, design and management. Desires position preferably as etxension agricultural engineer of experimental or production manager work. MA-133.

AGRICULTURAL ENGINEER wants responsible position in Canada in experimental or engineering work. Experienced wood patternmaker and draftsman. Eight years with present employers as patternmaker and later in charge of experimental work. Age 35 years and married. Wants position with better opportunity for growth. MA-139.

AGRICULTURAL ENGINEER, 1925 graduate of Kansas State Agricultural College in agricultural engineering, now serving second year as instructor of farm mechanics in an agricultural school, desires position in experimental or extension work in agricultural engineering. Arrange for interview at A.S.A.E. annual meeting at St. Paul. Age 28. Married. MA-140.

AGRICULTURAL ENGINEER, graduate of Iowa State College in both agriculture and agricultural engineering. Ten years farm experience and nine years in engineering, extension, and teaching work. Prefers location on the Pacific coast with a permanent residence, experimental work, management of a ranch, or college teaching. Dependable and responsible. MA-141.

AGRICULTURAL ENGINEER, graduate in agricultural engineering, (B.S. in 1923; M.S. in 1924) desires position in experimental research work. Two years experiment station experience, five years industrial shop experience, eighteen months in employ of electric service company, one year teaching. Available upon reasonable notice. Age 27. Married. MA-142.

AGRICULTURAL ENGINEER wanted as instructor in farm motors and drainage. Single man who can also act as preceptor of boys' dormitory. Splendid opportunity for senior or graduate agricultural engineer who wants practical teaching experience. School term October 1 to April 1. Write A. C. Heine, Agricultural Engineer, West Central School of Agriculture, Morris, Minnesota.

AGRICULTURAL ENGINEER with ability along experimental and engineering lines wanted by a farm machinery manufacturer in the middle west. Should have training as a draftsman. Recent graduate preferred. PO-130.

INVENTIVE ENGINEER, experienced and practical, wanted by an agricultural implement manufacturer to design and perfect farm and garden tools. For the right man the position will be permanent and lucrative. PO-131.

AGRICULTURAL ENGINEER, graduate of Cornell University, with some training in electrical engineering and several years experience electrical work, including power and rural telephone, wants position with electric power company or large agricultural development as agricultural engineer. Experienced in college teaching and extension work and as field expert by a large farm machinery manufacturer. Diplomatic with farmers. Location in East preferred. MA 143.

FACTORY MANAGER, trained both as mechanical and construction engineer with several years in responsible charge of factory production including plant engineering, building and remodeling works, directing the design of dies, tools and equipment, and also the design of farm machinery, desires position where general manager wants to be relieved of responsibility of factory production. Thoroughly versed in mechanics pertaining to the farming and the farm equipment industry. Has a thorough knowledge of cost accounting and modern methods of factory production, also field experience in the United States and Canada. Also has good knowledge of foreign requirements in Europe, Russia, South Africa and Australia. MA 144.

Positions Open

SALES MANAGER OR ASSISTANT SALES MANAGER WANTED. Agricultural engineer with sales experience preferred. Ample opportunity for advancement. Business now doing $500,000 volume on a varied line of farm equipment items in ten central western states. PO-122.

AGRICULTURAL ENGINEER, recent graduate, wanted by farm equipment manufacturer to take over work of demonstrating and introducing new tractor guide. Must be able to handle tractors in the field, make some designs, take orders, and eventually look after advertising and sales. PO-123.

U. S. CIVIL SERVICE OPENINGS

The U. S. Civil Service Commission announces open competitive examinations for associate farm fire prevention engineer ($3,000 a year) and assistant farm fire prevention engineer ($2,400 year). These positions are under the Bureau of Chemistry, U. S. Department of Agriculture. Applications must be on file with the Civil Service Commission at Washington, D. C., not later than July 26, 1927. Applicants should apply for Form 2600, stating title of ington, D. C.